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AND
RELATED ITEMS

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VOLUME 6

BY
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PREFACE

This volume represents a continuing effort to cover comprehensively the unclassified information on explosives and related subjects in the same manner and format as in previous volumes. The reader is urged to obtain the previous volumes and to read both the PREFACE & INTRODUCTION in Volume I in order to understand the authors' way of presenting the subject matter.

In preparation for and during the writing of this Encyclopedia, the authors have consulted freely with and have had the cooperation of many individuals who contributed their expert knowledge and advice. This fact is acknowledged throughout the text at the end of the subject item. A listing of many others who have helped in various ways would be impractical.

Scientists at the Franklin Institute Research Laboratories, Philadelphia, Pennsylvania (See overleaf) have contributed significantly in the organizing, literature searching and writing of much of the manuscript for this volume.

Dr R.F. Walker, Explosives Division Chief, has provided financial support and encouragement to continue this work to its conclusion. Further financial support is expected from the sale of copies to non-governmental agencies and individuals by the National Technical Information Service, US Department of Commerce, Springfield, Virginia 22151. This additional source of funds will permit future volumes to be published much sooner.

Although considerable effort has been made to present this information as accurately as possible, mistakes and errors in transcription and translation do occur. Therefore, the authors encourage the readers to consult original sources, when possible, and to feel free to point out errors and omissions of important works so that corrections and additions can be listed in the next volume. The interpretations of data and opinions expressed are often those of the authors and are not necessarily those nor the responsibility of officials of Picatinny Arsenal or the Department of the Army.

This report has been prepared for information purposes only and neither Picatinny Arsenal nor the Department of the Army shall be responsible for any events or decisions arising from the use of any information contained herein.
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SUPPLEMENT TO THE
LIST OF BOOKS ON EXPLOSIVES AND PROPELLANTS
GIVEN IN VOL 1, p A676; VOL 2, pp C215 to C216; VOL 3, pp XIV to XV;
VOL 4, pp LI to LV AND VOL 5, pp XIV to XV


I.N. Bradley, "Flame and Combustion Phenomena", Halsted, NY (1972), 210pp


E. Ya Orlova, "Chemistry and Technology of High Explosives" (Khimiya i Tekhnologiya Brizannykh Vzryvchatykh Veshchestv), 2nd Ed, Khimiya, Leningrad, Otd, Leningrad, Russia (1973), 688pp

Sh.B. Bagdasarow, A.O. Vercheba, N.I. Kulichikhin, I.I. Pal'mov and A.D. Pashkov, "Handbook for a Mining Specialist in Geological Prospecting Groups with Special References to Properties of Explosives" (Spravochnik Gornogo Mestna Geologorozvedchnykh Partii), 2nd Ed, Nedra: Moscow, Russia (1973), 368pp


R. Liepens, R.W. Handy & J.W. Harrison, "Characteristics of Non-Military Explosives", Research Triangle Inst, Durham, NC (Feb 1974), 81pp (AD-778207/1WY) (Describes the compn of commercial exps and expl materials used for clandestine bomb fabrication)


Alphabet letter E begins in Vol 5, p E1
Etrogenguss. German for Multiple-Pouring or Step-Loading method used during WWII for filling (Füllung in Ger) of large-caliber shells, such as of 15cm and 21cm. The method is described under "Loading of Ammunition".

Etching Reagent Explodes. Under this title Drs M.S. Frant & H.A. Fox Jr of AMP, Inc, Harrisburg, Pa stated (Ref 1) that 40ml of a well known etching reagent, prepd by them on mixing equal parts of acetone, concd nitric acid and 75% acetic acid, exploded about 4 hours after it was prepd and placed in a closed bottle.

It was later suggested by W.J. Secunda of St Louis, Mo (Ref 2), that the formulation given in Ref 1 is very similar to that given for the prep of TeNMe (Tetranitromethane). For its prep, equal parts of acetic anhydride and concd nitric acid are allowed to stand for a few days. Since TeNMe is a good reagent for revealing a double bond (producing an intense yellow color with the same), it is suggested to test the etching soln of Ref 1 for the presence of TeNMe by bringing it in contact with an unsaturated compd.


Note: It might be of interest to know that TeNMe can be prepd by the action of hot fuming nitric acid plus concd sulfuric acid on Nitroform, as was done by Schischkoff in 1861 (Ann 119, 247). The method of prep of TeNMe from Ac₂O & HNO₃ was described by F.D. Chattaway, JCS 97, 2100 (1910). TeNMe is always present in small quantities in products of nitration of benzene, toluene, phenol, etc and can be recognized by a pungent odor.

Ethanoamide. See Acetamide in Vol 1 of Encycl, p A16-R.

Ethanamidine, Ethaneamidine or Ethynylamidine. See α-Amino-α-imodoethane in Vol 1, p A223-L.

Ethandiol-1,2. See Ethyleneglycol or Glycol.

ETHANE AND DERIVATIVES

Ethane (Ethylhydride, Dinaethyl, Methylmethane), H₂C₂H₆; mw 30.07; colorless & odorless gas, s denser than air (1.04 vs 1.00 at 0° & 760mm); sp gr of liq 0.546 at -88°; fr p -183.23° (triple point); heat of combst 22300 Btu/lb 1 and expl limits in air (% by vol) lower 3.2 and upper 12.5. It is very sol in alc and moderately sol in water. It can be prepd by one of the following methods: fractionation from natural gas, petroleum or shale oil gases; also by passing alcohol vapor over amorphous Al at 360°.

Its azide and nitro derivatives are explosive.


Ethane Azide, Azidoethane, Ethyl Azide or Triazoethane, H₂C₂H₆(N₃); mw 71.08, N 59.12%; liquid, sp gr 0.8765 at 25/4°; nD 1.3928 at 25°; fr p not reported; bp 48.8-50° at 766mm; detonates at higher temp; stable at RT. It can be prepd by warming concd soln of Na azide with diethyl sulfate (Refs 1, 2 & 5). Campbell & Rice (Ref 3) investigated its phenomenon of expn and decided that it is apparently purely thermal, i.e., due to the accumulation of heat of reaction within the gas. The same scientists (Ref 4) investigated expn of Azidoethane in the presence of diethyl ether.


Ethene, Azidochloro or Chloroethyl Azide. See under Chloroethene in Vol 3 of Encycl, p C254.

Ethane Azidonitrate, Ethylazide Nitrate or Azidoethyl Nitrate, N₃(CH₂)₂CH₂ONO₂; mw 132, N 42.4%, OB to CO₂ -36.3%; toxic liquid, sp gr 1.34, fr p minus 20° bp - decamp and expl at 180°, when heated at the rate of 25° per min. It is appreciably volatile. It is sol in benz, alc & eth; insol in water. It can be prepd by nitrating N₅CH₂-CH₂-OH with mixed.
Acid (Refs 1 & 4) 
Expl mixts are formed from Ethane Azido-
nitrate, NG, NaNO₃, wood meal & CaCO₃ or 
other mixts (Ref 2) 
AzeN gelatinizes NC and resembles in 
its physiological and explosive props NC 
and NG 
Blatt (Ref 3), Urbadiski (Ref 4) and ADL 
(Ref 5) give the following props of AzeN: 
Impact Sensitivity: For a 50/50 mixt with 
sawdust, the max fall for no shots with a 
10 lb wt was 2". The corresponding values 
for NGc and NG were 5" and 6", respectively. 
Absorbed on filter paper the pure liq could be 
detonated by the blow of a hammer 
Power by Ballistic Mortar – 141% TNT 
Power by Trauzl Test – 150% TNT 
Velocity of Detonation – 1985 and 6550m/sec 
at sp gr 1.34 
Refs: 1) Beil 1, [1365] 2) F.H. Bergeim, 
USP 1620714 & 1620715 (1927) & CA 21, 
1551 (1927) 3) Blatt, OSRD 2014 (1944) 
(Azido) 4) T. Urbanski, IX Cong.Intern-
Quim Pura Applicata 4, 438 (1934) & CA 30, 
3649 (1936) 5) ADL, PureExplCompds, 
Part 1 (1947), pp 48 & 150 

Ethane Diazone; Diazoethane, Ethyldiaze 
or Bistriaethane, H₃C.CH(N₃)₂; mw 112.10, 
N 74.98%, OB to CO₂ –85.6% 
The following isomers exist: 
Ethene-1,1-Diazio or 1,1-Diazoethane 
(1,1-DazEt), solid, extremely unstable, even 
at RT. The first attempt to prep it in 1908 
(Ref 2) failed because a dangerous expln 
occd and its prep was not repeated 
Refs: 1) Beil – not found 2) M. Forster 
et al JCS 93, 1073 (1908) 

Ethene-1,2-Diazio or 1,2-Diazoethane 
(1,2-DazEt) or 1,2-Bistriaethane, 
N₃.CH₂.CH₂.N₃; oil with chlf-like odor, 
sp gr 1.178 at 19/19°, fr p – not reported, 
bp 53° at 9mm; explodes when thrown on a 
hot plate. It can be prep by heating ethanol, 
edhy chloride and Na azide in water 
It is an expl nearly as powerful as TNT 
(97% by Trauzl Test) and moderately sensitive 
to friction and impact 
Refs: 1) Beil 1, 103 & 12041 2) M.O. 

Forster et al, JCS 93, 1071 (1908) 3) Blatt, 
OSRD 2014 (1944) 4) ADL, PureExplCompds, 
Part 1 (1947), p 44 

ETHANE NITRATED AND NITROSATED 
DERIVATIVES 
Ethane Nitrate, Ethyl Nitrate or Ethane Nitric 
Ester (Ethyl Nitrat or Salpetersäure-äthylester, 
in Ger), H₃C.CH₂ONO₂; mw 91.07, N 15.38%, 
OB to CO₂ –61.5%; colorless, pleasant 
smelling, volatile liquid which can be easily 
ignited by flame; sp gr 1.044 at 25/25°, or 
1.116 at 15°, nD 1.387, fr p –102° (~112°); 
bp 87.5°, fl p 34°F; vapor density 3.14 (Air 1.0). 
It is sl sol in w (1.3% at 53°) and is miscible 
with alc or ether; gelatinizes colloid cotton. 
It was first prepd by Millon in 1843 by treating 
absol alc with nitric acid (d 1.4) in the 
presence of urea which served to eliminate 
lower N oxides (Ref 1, p 329 & Ref 1a). A 
modified Millon method is described by Naoum 
(Ref 2a). The highest yield obtained by 
method of Millon and its modifications was 
only 35%. Ville (Ref 6) describes in detail 
the procedure which is claimed to give a yield 
of 85% (calcd on consumed alc) 
Procedure. Introduce into a 3-neck, round-
bottom flask of 350ml capacity (provided with 
an agitator and an ice-water cooling bath) 
80g of mixed acid of approx compn: HNO₃ 
53, H₂SO₄ 42 & SO₃ 5%. The acid is obtd 
by mixing, with stirring and cooling, calcd 
quantities of 95% strong HNO₃ (freed from 
lower N oxides either by urea or by bubbling 
through dry air at 60°) and ca 20% strong oleum. 
When the temp of mixed acid reaches ca 10°, 
add drop by drop a mixt of 26g alc (95% 
strong) & ca 2.5g urea, while stirring and 
maintaining the temp at 10–15°. Transfer 
the liquid to a separatory funnel, stopper it 
and shake gently. Remove thru the stopock 
the lower (acid) layer and discard it. Wash 
the liquid remaining in the funnel, first with 
20ml of iced w and then with 20ml of cold 2% 
Na carbonate soln. For drying and eliminating 
residual acid, add few grams of anhyd 
Na carbonate and transfer EtN into weighing 
flask. By using this method, Ville obtd 
185g of product of d 1.102, which was 96–97% 
pure. When ignited, the product burns quietly 
with clear flame, but Ville could not expld 
it by impact or by a detonator contg Ig MF 
(Ref 6, pp 79–80)
Naoún (Ref 2a) gives the following props:
Notwithstanding its high negative oxygen balance, it is a powerful and brisant expl.
With decompn accdg to the equation:
\[ 2C_2H_5ONO_2 = 4CO + 2H_2O + N_2, \]
the heat of expln may be calcd, if the heat of formation is taken as 48.5 kcal/mole, as given in Ref 2, p 207. The heat of expln arrived at in this manner is 712.6 kcal/kg at C_2 and H_2O gas or 816.3 kcal/kg with H_2O liquid. These values are about 50% of those for NG (1485 and 1585 kcal/kg).

Schmidt (Ref 3) gives a different value for its heat of formation, namely 33.7 kcal/mole or 370 kcal/kg (vs 82.7 kcal/mole & 364 kcal/kg for NG). He also gives heats of combustion at C_2, H_2O liquid (3561 kcal/kg for EtN & 1631 for NG), but no heats of expln.

Blatt (Ref 4b) gives its heat of combatn at const vol as 324 kcal/mole. Hutchison (Ref 5a) gives its CVWL (calorific value, water liquid) as 850 cal/g.

Blatt (Ref 4b) gives its power by Ballistic Mortar Test as 123% TNT, while by Trauzl Test 345 sec for 10 g sample initiated by No 8 blasting cap and under water rapping. This value is about 58% that of NG (590 cc). EtN is rather insensitive to detonation and is less sensitive to shock or friction than NG or NGc. It can be detonated with No 8 cap when confined or when mixed with some powdery material, such as kieselguhr. In the latter case it can be initiated without confinement. Its detonation velocity was detd indirectly in mixts consisting of EtN 60 to 70 & kieselguhr 40 to 30% and was found to be of the magnitude of 6000 to 7000 m/sec (Refs 2a & 4a).

It is stable in storage at ordinary temps.

In Ref 4 are given its flash point as 50°F (in open or closed cup) and its lower explosive limit in mixts with air as 3.8% by vol. No upper limit is given. In Ref 5 is discussed its detonation by impact and in Refs 7 & 8 are briefly discussed its toxicity and fire & expln hazards. Hutchison (Ref 5a) gives its specific impulse (theoretical) as 197, viscosity 0.6c/s/stokes at 20° and temp of decompn 1600°. It will only propagate detonation in a pipe of diam greater than 1¼ inches.

Accdg to Midgley & Boyd (Ref 2), EtN added in a small quantity to a liquid fuel used in internal combustion engines accelerates the combstn.

Uses: Medicine, organic synthesis, commercial expls and liquid rocket propiants (Refs 2, 2a, 5a, 7 & 8).

Hutchison (Ref 5a) discusses in detail the use of EtN in liq rocket propiants. The use of EtN is not recommended as a means of operating aero engine starters, or for any other operations where the unit is to be repeatedly used in close proximity to human life.

It was recommended in France as a dope for fuels intended for use in two-cycle engines (moteurs à deux temps).


Addnl Refs: A) N.V. Sidgwick, "Organic Chemistry of Nitrogen", Oxford Univ Press, London (1937), pp 8 & 250 [EtN may be used for some difficult nitratons, as for example to 1,3,6,8-Tetranitrocubazol in presence of sulfuric acid. It has been chiefly used, however, for replacing a hydrogen in a reactive methylene group by NO under the influence of Na ethoxide:

\[ \text{R.CH}_2\text{COOC}_2\text{H}_5 + \text{C}_2\text{H}_5\text{NO}_2 + \text{KOC}_2\text{H}_5 \rightarrow \text{R.C(NO.OK).COOC}_2\text{H}_5 + 2\text{C}_3\text{H}_5\text{OH} \]

A weaker action is obt at when EtN reacts in presence of AlCl_3, as for example benzene or toluene are nitrated to mono-stage].


E. L. Médard, MP 36, 75 (1954) & CA 49, 16435 (1955) (Expl props of EtN)
F) R. Vandoni & M. Laudy, Mèm Services Chim. Etat 40, 187 (1955) (Vapor pressure in mm: 9.1 at -10⁰, 16.5 at 0⁰ and 30.5 at 10⁰)
H) G. Desseigne & R. Robussier, MP 39, 172-79 (1957) (Prepn of EtN)
I) G. Desseigne, FrP 1164368 (1958) & CA 53, 461 (1959) (Continuous method of prepn)

Ethane Nitrite, Ethyl Nitrite, Ethane Nitrous Ether or Nitrosoxyethane (i.e. Ethyl Nitrit or Salpetri gäüre-äthylester, in Ger), H₃C.CH₂ONO; mw 75.07, N 18.66%; it ycl, volatile & flammable liq or gas; sp gr 0.900 at 15.5⁰, vapor density 2.59 (Air 1.0), fr p - not given, bp 17⁰; v sl sol in w, miscible with alc or eth. It was 1st prepd in 1861 by Kunkel in impure state by treating ethanol with nitrous acid (Ref 1). Wallach & Otto (Ref 2) prep'd it by treating ethanol with Na nitrite in presence of sulfuric acid. It was also prepd by Strecker & Spitaler (Ref 3). Adickes (Ref 4) describes a special apparatus in which is automatically achieved complete mixing of aq alcohol-Na nitrite and sulfuric acid in order to avoid the sudden dangerous evolution of gas during nitritification. Detailed description of prep is given in OrgSynth (Ref 5). Two methods of prep are listed in CondChemDict (Ref 8): a) By the action of nitrous oxide gas on ethanol; and b) By treating ethanol with alkali nitrates and sulfuric acid.

In Ref 4 is given its fl p as 30⁰F in open cup & 31⁰F in closed cup and its exp limits in mixts with air 3.1 to >50% by vol. Toxicity and fire & expl hazards are discussed in Refs 7 & 8. Its explosibility is discussed in Ref 6.

Ethyl Nitrite has been used in medicine under the name "spiritus aethers nitrosi"

7) Sax (1957), 698 8) CondChemDict (1961), 475 9) Kirk & Othmer, 2nd edit, not found

Nitrosoethylene (N₂OEt) or Nitrosoethyl, CH₃.CH₂NO; mw 59.07, N 23.71%; wh waxy solid having a sweet penetrating odor, mp 58-62⁰ to a blue liq which became pale green as the temp rose; the liq charred at 138⁰. It was formed, with other products, when dim-butymercury, Bu₂Hg, was pyrolized in the presence of NO as carrier gas in the temp range 376-410⁰ (Ref 2). It was also formed at temps above 100⁰ by the addn of ethane to NO₂ (Ref 3). Its prep by photolyzing ethyl iodide in the presence of NO and the kinetics of the reaction are reported by Christi et al (Ref 3).


Nitroethane or Nitroethyl (NEt) (Nitrothan, in Ger), H₃C.CH₂.NO₂; mw 75.07, N 18.66%, OB to CO₂ -95.9%; colorless, flammable liq; sp gr 1.052 at 20/20⁰; fr p -90⁰, bp 114⁰ at 760mm, vapor pressure 15.6mm, flash point (Tag open cup) 106⁰F, np 1.3971 at 20⁰; heat of contsm 429cal/g, heat of formation 472cal/g; sl sol in w; v sol in alc, eth or chl; sol in acids and alkalies.

It was 1st prepd in 1894 by Nef (Refs 1 & 2) by nitrating ethane. Accdg to CondChemDict, NEt can be prepd by treating ethane with oxides of nitrogen or with nitric acid under pressure (Ref 9). In the method of prep listed by Fieser & Fieser (Ref 7), vapors of ethane pass together with vapors of nitric acid thru a narrow reaction tube at 420⁰. Accdg to Hibahan et al (Ref 4), vapor-phase nitration of ethane produces a mixture of C₃H₆NO with C₂H₄NO₂. In the lab method of prep by Desseeigne & Giral (Ref 8), pure NEt is produced starting from ethanol, oleum and Na nitrate. It is stated, however, that the method is not suitable for industrial purposes because it cannot compete with vapor-phase nitration of propane which renders...
considerable proportion of NET. In the lab method of McCombie et al (Ref 6), NET was
prepd by the action of Na nitrite on ethyl sulfate: 
\[
\text{C}_2\text{H}_5\text{O} \cdot \text{SO}_2 \cdot \text{OC}_2\text{H}_5 + \text{HNO}_2 \rightarrow \text{C}_2\text{H}_5\text{O} \cdot \text{SO}_2 \cdot \text{Na} + \text{C}_2\text{H}_5\text{NO}_2
\]

Aced to McKittrie et al (Ref 3), NET explodes at 450° after few minutes of heating. 
Blatt & Whitmore (Ref 5) found it difficult to detonate.

It can be used as a solvent for NC in prepn of propellants.

Salts of NET

Sodium and potassium salts were first prepd and examined by Neff (Ref 2). For their 
prepn of NET was dissolved in ether and treated with Na or K alcohohlates (obtbd by "dissolving 
metallic Na or K in alcohol). Both C_2H_4(NO_2)Na 
and C_2H_4(NO_2)K are soln in w and very sol 
in alc. The Na salt defgr on heating & 
explodes at high temp. The Thalium salt, 
TIC_2H_5NO_2, crysts (from aq alc), dec at 
80–82° (Ref 1)

Refs: 1) Beil 1, 99, (32), [70] & [199]
2) J.U. Neff, Ann 280, 273 (1894) 3) D.C.
McKittrie et al, IEC(AnAlEd) 10, 63 (1938)
4) H.B. Hibshman et al, IFC 32, 437–29 
(1940) 5) A.H. Blatt & F.C. Whitmore, 
OSRD 1085 (1942), 63 6) H. McCombie et 
al, JCS 1944, 24–5 7) L. Fieser & M.
Fieser, "Organic Chemistry", Heath & Co, 
Boston (1950), 48 8) G. Desseigne & H.
Girard, MP 34, 49–53 (1952) 9) CondChem-
Dect (1961), 803-R & 804-L.

Dinitroethanes (DNET), C_2H_4(NO_2)_2; mw 
120.07, N 23.33%, OB to CO_2 – 26.7%

The following isomers exist:

1,1-Dinitroethane (1,1-DNET), (O_2N)_2CH.CH_2; 
colorless oil with faint alcoholic odor; f _p_ not 
reported; bp 185–86° at 760mm and 73– 
75.4° at 13mm, n_0D_1 1.4340 at 20°; sp gr 
1.3503 at 23.5°

It can be prepd by acidification of pota-
tassium-1,1-dinitroethanate, first prepd in 
1876 by Ter Meer (Refs 1 & 2). In A.D.
Little Inc Rep (Ref 6, pp 81, 107 & 108), 
the prep of the Potassium salt is described 
using Ter Meer's method, as modified by 
Jacobson (Ref 4). For this, to 1-chloro-1-
nitroethane (listed in Vol 3 of our Encycl, p 
C254-R) dissolved in methanol, was added 
at about 0° an aq soln of K nitrate. A short

time after the start of addition (temp reached 
about 5° but below 10°) a stream of methanolic 
KOH soln was started to be added. The 
addn of the two solns was at such a rate that 
addn of KNO_2 was completed just before 
that of the KOH soln. The salt was collected 
on a filter funnel and washed with ice water 
& then cold methanol. The crude product 
was recrystd from water.

Bright yel crysts of K C_2H_4(NO_2)_2 obtbd 
exploded at 150°. The same salt can be 
used on treating 1-bromo-1-nitroethylene (Vol 
2 of Encycl, p B311-R) with K nitrite in alco-
holic soln of KOH (Ref 3). It explodes 
violently by impact.

For prepn of 1,1-DNET, ADL Rept (Ref 
6, p 108) recommends acidifying the K salt 
by means of 85% phosphoric acid and puri-
ifying the resulting product by vacuum dis-
tillation behind a barricade. A small amt of 
boric acid was added before the distillation 
operation. The water-white distillate boiled 
at 73–74.5° at 13mm pressure.

Blatt (Ref 5) lists the following props 
of 1,1-DNET:

Power, by Ballistic Mortar Test – 138% TNT 
Sensitivity to Impact – comparable with PETN 
Stability at RT – decomposes with evolution 
of nitrogen oxides on standing for several 
weeks

Thermal Stability at 135° – acidic in 30 min 
and no exphn in 300 mins

Uses: In AD Rept (Ref 6, p 108) is 
described the use of 1,1-DNET or its K salt 
in prepn of so-called Compound 335, which is 
of unknown structure but considered by some 
investigators to be 2,2,3,3-Tetranitrobutane:

\[
\text{NO}_2 \quad \text{O} \quad \text{NO}_2
\]
\[
\text{H}_3\text{C} - \text{C} - \text{N} = \text{C} - \text{CH}_3
\]
\[
\text{O} \quad \text{NO}_2
\]

or

\[
\text{NO}_2 \quad \text{NO}_2
\]
\[
\text{H}_3\text{C} - \text{C} - \text{O} - \text{N} = \text{C} - \text{CH}_3 \quad \text{CH}_3 - \text{C} - \text{C} - \text{CH}_3
\]
\[
\text{NO}_2 \quad \text{NO}_2
\]
\[
\text{NO}_2
\]

Reactions of 1,1-DNET with its salts are 
described in Ref 7. The Ammonium salt, 
NH_3C_2H_5(NO_2)_2, yel salt, mp 90–93° (dec) 
was prepd and so were others of 1,1-
DNET.

Refs: 1) Beil 1, 102, (32) & [70] 2) E.
Ter Meer, Ann 181, 1 (1876) 3) H. Wieland & E. Sakellarios, Ber 52, 904 (1919)

1,2-Dinitroethane, (O2N)CH2-CH2(NO2), white crystals from MeOH or benz, mp 39-40°, bp 135° at 5mm press; slowly decomps on storage; insol in w (Refs 1 & 4); can be prep'd in 70-80% yields by passing ethylene, C2H4, into nitrogen tetroxide, N2O4, at -10°. The yield reported in Blatt (Ref 3) was only 20-30%

It reacts with urea forming Nitroethylene:

\[ \text{CH}_2\text{NO}_2 + \text{CO(NH}_2)_2 = \text{CH}_2 + 2\text{N}_2 + \text{CO}_2 + 3\text{H}_2\text{O} \]

When heated with PETN at 100°, 1,2-DNET reacts very violently.

The following props are given in Blatt (Ref 3):
- Friction Sensitivity - very insensitive
- Impact Sensitivity - less sensitive than PA
- Initiation Sensitivity - very insensitive when cast
- Power, by Traulz Test - 146% PA
- Power, by Ballistic Mortar - 91% of Blasting Gelatin

Stability - unstable showing acidic on standing

1,2-DNET was also prep'd and examined during WWI by Ipatow (Ref 2). See Ref 4 which questions the identity of product obt'd as gm-yel oil, bp 94-96° at 5mm press


Trinitroethanes (TNET), C2H3(NO2)3, mw 165.07, N 25.46%, OB to CO2 18.45%

The following isomers exist:
1,1,1-Trinitroethane, (O2N)3CH3, Small white, very volatile cubic crystals; sp gr 1.4223 at 77.7°, mp 56-57°, bp 68° at 17mm press; explodes at higher temp; v sl sol in w and in cold ligroin; sol in alc, eth and in most org solvents; heat of combst at C2 1777cal/g.

It detonates by a hammer blow; can be prep'd by the action of a cooled ethereal soln of silver nitroform on an excess of methyl iodide: C(NO2)3Ag + CH3I = C(NO2)3, CH3 + AgI. After allowing the mixture to stand for a short time, it is filtered to remove AgI and the filtrate evaporated in vacuum. In the method of prep'n described in US Rubber Rept (Ref 4), K nitroform was dissolved in acetone and treated with methyl iodide; mp of TNET was reported as 53-4°, while Hantzsch & Rinckenberger (Ref 2) gave 56°.

In US Rubber Rept No 25 (Ref 6) is described the method according to Rohm & Haas Co Quart.Rept No 52-3, Sept 1952, p 12. See Refs for addnl methods of prep'n and for other props:


1,1,2-Trinitroethane, (O2N)2CH.CH3(NO2).
This compd is listed in Table 139 of Ref 2, as compound 569. No refs as to its prep'n & props were found in the literature
Refs: 1) Beil - not found 2) ADL Pure-Expl Compds, Part 4 (1952), p 570

Tetranitroethanes (TeNEt), C₆H₄(NO₂)₄, mw 210.07, N 26.67%, OB to CO₂ +22.8%

The following isomers are theoretically possible:
1,1,2,2 (or sym)-Tetranitroethane,
(O₂N)₂CH.CH(NO₂)₂. This compd could not be prepd but is known in the form of its salts, such as:
Dipotassium-1,1,2,2-Tetranitroethanate
(DKTeNET), K₂C₆(NO₂)₄; mw 286.25, N 19.57%, OB to CO₂ & K₂O +16.8%; small, glittering yel crysrs with violet tinge (from aq methanol; mp — explodes at 267–275°; v sol in w; sol in aq methanol; sl sol in methanol, alc, acet, benz, chlf & AcOH. It was first prepd by Scholl & Brenneisen (Refs 1 & 2). Further work was done by Scholl & Schmidt (Ref 3) and Will (Ref 4). The yields were very poor because many side reactions took place, in addition to the following main reaction:
2C(NO₂)Br₂ + KCN = KBr + BrCN + Cyanogen bromide
C(NO₂)Br₂.C(NO₂)Br₉
Tetrabromodinitroethane

C(NO₂)Br₂.C(NO₂)Br₂ + 2KNO₂ = 2KBr + C(NO₂)₂Br.C(NO₂)₂Br
Dibromotetranitroethane

C(NO₂)₂Br.C(NO₂)₂Br + 2KCN = 2BrCN + C(NO₂)₂K.C(NO₂)₂K
Dipotassium Tetranitroethane
(or 2KNO₂ = 2BrNO₂ (Nitryl bromide)

Due to the fact that the salt is extremely sensitive, especially when in an impure state, it is advisable to prepare it in smaller quantities than was suggested by Will (Ref 4)
Laboratory Procedure:
(Work should be done behind a protecting screen of safety glass or plastic). Dissolve about 50g of bromopicrin in about 25ml of methanol (contained in a 400ml beaker immersed in a bath with tap water) and add slowly, with constant stirring and cooling, 25g of finely powdered potassium cyanide, followed by a solution of 12.5g of potassium nitrate in about 40ml of water. Do not allow the temperature of the mixture to rise above 30°. Stir for an additional 1/2 hour, cool in an ice-salt bath (to get better yield) and filter the pptd salt thru a Büchner funnel. Dissolve the precipitate in the smallest amount of warm water containing a small amount of KOH (to render alkaline), and crystallize by freezing the solution in an ice-salt bath. Remove the crystals by filtration and dry them at 80–90°. Yield about 8.5g. Keep the crystals in a beaker wrapped on the outside with a piece of cheesecloth (this is recommended because the salt is very sensitive and might accidently explode)

Other methods of preparation are described by Hunter (Refs 5 & 6) and by Houben (Ref 8)
DKTeNET is an explosive of the initiating class and is extremely sensitive to friction, impact and heat, especially if not properly purified.

The salt was prepd at Picatinny Arsenal in 1930 by S. Livingston (Ref 7) and then in 1947 by Dr K.S. Warren. However, the compound was considered too dangerous for use as a military explosive and work on it discontinued after what was supposed to be some of the salt exploded in a beaker resulting in the death of one chemist, Dr P.F. Macy
Silver Tetranitroethanate, Ag₂C₂O₆N₄. Yellow-red crystalline compound, insol in w, alc & ether; was first prepd by Scholl and Brenneisen (Ref 2, p 649) by adding a concd aq solution of 1.7g of AgNO₃ to a cold concd aq solution of 1.5g of dipotassium tetranitroethanate. After allowing to stand for a while, the salt crystallized out and was obt'd by filtering the mixture thru a small Büchner and washing with alcohol and ether

It is a very mild explosive practically insensitive to impact
Lead Tetranitroethanate, PbC₂O₆N₄. Brown crystalline compound, claimed to have been prepd by S. Livingston (Ref 7) by dissolving 1g of the potassium salt in about 25ml of water and adding to this about 15ml of water containing 1.3g of lead acetate. The precipitated lead salt was filtered, washed with w, alcohol & ether. It was insol in w, alc and edh and was a mild expl, practically insensitive to impact. When brought into contact with a flame, it burned rapidly without expl
Ref: 1) Beil 1, 103, (33), [70] & 1 204
2) R. Scholl & M. Brenneisen, Ber 31, 646–47 (1898) 3) R. Scholl & A. Schmidt, Ber 35, 4288 (1902) 4) W. Will, Ber 47, 963–64 (1914)
9) F.G. Borsardo et al, JOC 31, 9, 2806 (1966) & CA 65, 13523 (1966) (Prepn of Dipotassium salt from 1,1,1-trinitroethane by treatment with nitrite ion in basic media)

1,1,1,2-Tetranitroethane, \((O_2N)C\cdot CH_2\cdot NO_2\).

No information at our disposal that it was ever prep'd; not found in the literature thru 1966

1,1,1,2-Pentanitroethane, \((O_2N)C\cdot CH(NO_2)_2\).

No information at our disposal that it was ever prep'd; not found in the literature thru 1966

**HEXANITROETHANE (HNE)** (Called Hexanitroethan, in Ger), \((O_2N)_3C\cdot (NO_2)_3\); mw 300.07, N 28.01%, OB to CO or 42.7%; colorless cryts (from ether), nonhygroscopic, sl volatile at RT; mp 142° (with sublimation and partial decomp); explodes mildly on rapid heating above 360° and by action of a detonator. Soluble in ether, benz, petr eth & chlf; diffc sol in ethanol; insol in water

It was prep'd in 90% yield by Will (Refs 1 & 3), but in 1913 it was patented by Claessen for use as an ingredient of expls (Ref 2 and Vol 3 of Encycl, p C325-R). Will (Ref 3) prep'd HNE in 1914 by nitrating a concd sulfuric acid soln of pure Dipotassium Tetrinitroethanate (qv) with mixed nitric-sulfuric acid at 5 to 10°C. Prep of dipotassium salt from bromopircin and potassium cyanide is described above under Tetrinitroethane. In the method described by Houben (Ref 7), a 100g sample of dipotassium salt is used. As such a big sample is too dangerous for laboratoty method, we suggest reducing it to 10g and proceeding as follows (while working behind a safety screen, under a hood): Dissolve a 10g sample of very pure DKTetNE in 50ml of concd sulfuric acid, with constant stirring and cooling to 5°C. Then add slowly the mixed acid (consisting of 15ml nitric acid of sp gr 1,52 and 15ml concd sulfuric acid), with stirring and cooling. Raise gradually the temp to 60–70° and maintain it for 10 mins. Then cool in ice bath and drawn immediately in a large volume of ice-water. Filter by suction thru a sintered glass Büchner funnel, wash cryts of HNE with cold w, dry them by passing air and dissolve in ether. Add some powdered CaCO_3 to neutralize the acidity, filter and evaporate the ether by air. The yield was claimed by Houben to be 90% of theory.

**Note:** If Dipotassium Tetrinitroethane is not pure, it will ignite immediately on contact with concd sulfuric acid

HNE was also prep'd at the Natl Fireworks (Ref 10) and the US Rubber Co Lab (Ref 11). Noble et al (Ref 15) reported some of its physical and chemical properties:

- **Explosive Properties of HNE**: [as listed by Will (Ref 3), McGill (Ref 7a), Blatt (Ref 8) and ADL (Ref 9)]
- **Impact Sensitivity**: comparable with PETN (Fl)
- **Power by Ballistic Mortar Test**: 108% TNT
- **Power by Traul Test**: 115% TNT

**Thermal Stability at 135°**: acidic in 30 mins

**Uses:** Due to the presence of excess O, HNE forms in mixts with HE's deficient in O, very powerful expls. Claessen (Ref 2) patented in 1913 several mixts with TNT suitable as bursting or booster ches of artillery shells. Some of them, such as HNE 45 & TNT 55% are listed in Vol 3 of Encycl, p C325-R. He also patented its use in manuf of artillery proplnts, such as: NC 68, HNE: 16, TNT 9 & Cenr 1%, listed in Vol 3, p C326-R. A blasting expl cong HNE: 64 & TNT 36% was claimed to be more powerful than Blasting Gelatin. These expls are also listed in Colver (Ref 5). During WWI HNE was used in "Big Bertha" ammunition. Big Bertha, also known as "París Gun" (Parisgeschütz or Pariserfein, in Ger) is briefly described in Vol 2 of Encycl, p B113-R

Hannum (Ref 12) patented mixts of fuels, consisting of NMe (Nitromethane), NEt (Nitroethane), and mono-, di-, or trinitropropane, with oxidants HNE or TeNMe (Tetrinitroethane), stabilized by the addn of substituted ammonias in ants of 1 to 10% by wt. A preferred mixt is NMe 55:5 & HNE; or TeNMe 44.5%, with p-phenylenediamine or Centralite as a stabilizer

Hannum also patented (Ref 13) an expl

**Ethanemercarbide and Derivatives**

**Ethanemercarbide** (called Dianhydro-hexakis-[hydroxymercu(1)-thion, or Ethanemercarbide, in Ger), HO,Hg,(OHg)2:C(Hg2O)C.HgOH; mw 1293.69, OB to CO2 8.7%, yield powd, denatures at 230°C (183°C). It may be prepd by heating EtOH, PrOH, allyl-OH, amyl-OH, Ach, cane sugar, starch, or cellulose w/ yel HgO in alk soln; insensitive to impact, but crackles under friction; it dehydrates at 200–230°C prior to violent dem at 230°C; not depd by strong acid or alkali. *Ref 2b*

**Ethanemercarbide Dinitrate,** O2N.O.Hg,(HO,Hg)2:C(HgOH)2:HgONO3; mw 1419.73, OB to CO2 2.2%, yel-wh crysts; decomp on heating. It may be prepd by treating the parent cmpd with 10% nitric acid; insol in water & dill nitric acid. *Ref 2a*

**Ethanemercarbide Dinitrate Diammoniate,** C2H6.Hg6N4O6; mw 1417.76, OB to CO2 5.6%; may be prepd by treating the dinitrate with an AN-NH3OH soln for 6 hrs at 30°C. *Ref 2b*

**Ethanemercarbide Disulfate,** HO3SO.Hg,(HO,Hg)2:C(HgOH)2:Hg.O.SO3H; mw 1489.84, OB to CO2 7.5%, wh cryst powd; insol in w, decomp on heating; may be prepd by boiling the dinitrate with NaOH soln, then heating with 20% sulfuric acid. *Ref 2a*

**Disbetaethanemercarbide,** C3H2Hg2O5S2; mw 1325.82, OB to CO2 18%, yel powd. It may be prepd by treating the parent cmpd for several weeks in methanolic ammonium polysulfide. *Ref 2c*

**Ethanemercarbide Hexadiolate,** (Hg)2C.C(Hgl)3; mw 1989.20, OB to CO2 8%, red-yel cryst; may be prepd by treating one mole of the parent cmpd with 6 moles of EtI for 60 hrs at 90°C. *Ref 2b*

**Ethanemercarbide Hexachloride,** (CHHg)3C.C(HgCl)3; mw 1440.41, OB to CO2 11%; wh cryst, decomp on heating, sl sol in water, dill HCl; may be prepd by heating the parent cmpd with HCl soln. *Ref 2b*

**Dichloroethanemercarbide,** C2Cl2Hg6O2; mw 1330.59, OB to CO2 9.6%; may be prepd by heating the parent cmpd in a KCl soln, or treating the parent with 10% HCl at RT. *Ref 2b*

**Dichloroethanemercarbide Diammoniate,** C2Cl2Hg6N2O2; mw 1364.65, OB to CO2 12.9%; may be prepd by heating the dichloro derivative for 6 hrs at 40°C in ammoniacal NH3Cl. *Ref 2b*

**Ethanemercarbide Dichlorate or Dibromate,** explodes violently on heating or rubbing. *Ref 2c*
Ethanemercarbide Dipricechlorate, $C_2Cl_2H_8O_4$; mw 1458.59, OB 0%, wh powd, expl on heating or rubbing (with a green light); may be prepd by treating parent compd with $HClO_4$ (Ref 2b)

Ethanemercarbide Dipicrate, $C_4H_2H_8O_4N_6O_2$; mw 1751.79, OB to CO$_2$ -14.5%; yell solid; stronger deton on heating than K picrate (Ref 2a)

Ethanemercarbide Dichromate, $C_2Cr_2H_8O_4$, mw 1559.59, OB to CO$_2$ -1.0%; mild expln on heating (Ref 2c)

Following Refs were used for Ethanemercarbide and Derivatives:
Ref's: 1) Beil 2, 562-3  2) K.A. Hofmann et al, Ber a) 31, 1904, 2217 (1898); b) 33, 1329, 1332 (1900); c) 38, 3654 (1905)

Ethananitrite. See Acetonitrile in Vol 1 of Encycl, p A43

Ethane-phosphorous Acid, Esters, EtP(OR)$_2$; prepd by treating EtPCL$_2$ with CH$_3$OH (or C$_2$H$_5$OH) in ether in the presence of pyridine or Et$_3$N in a CO$_2$ atm. The Me and Et esters are odoriferous liquids which inflame spontaneously on exposure to air when spread on filter paper. The methyl ester, EtP(OMe)$_2$, has bp 73.5-74.5° at 225mm, d 0.9515 at 20°, n$_D$ 1.4210 at 20° and the ethyl ester, EtP(OEt)$_2$, has bp 58-60° at 38mm, d 0.9207 at 20° and n$_D$ 1.4212 at 20°.
Ref: B.A. Abuzov & N.I. Rizpolozhenski, DoklAkadNauk USSR 83, 581 (1951) & CA 47, 3226 (1953)

Ethane-tetacarboxylic Acid and Derivatives
Ethane-tetacarboxylic Acid (Åthán-tetra-carbonsäure, in Ger), (HO$_2$C)$_2$CH.CH.CO$_2$H)$_2$; mw 206.1, OB to CO$_2$ -54%, crys, mp 167-169° dec (Ref 7), 183° (Ref 12). It was first prepd in 1922 by reducing ethylene-tetra-carboxylic acid with palladium-on-carbon and hydrogen, then in 1924 by hydrolyzing the potassium salt obtained from the saponification of the tetraethyl ester (Ref 7)

Ethane-tetacarboxylic Acid Dianhydride, [3,7-Dioxo-2,4,6,8-tetra-o xo-bicyclo(3,3,0)-octane], mw 170.1, OB to CO$_2$ -66%, crys, dec over 150°. It was first prepd in 1920 by heating the acid in a six-fold excess of acetic anhydride at 70-75° then in 1923 by treating the acid with AcCl and heat, or by treating with oxalyl chloride, the acid or the tetra-silver salt of the acid (Ref 6)

Ethane-tetacarboxylic Acid Tetraethyl Ester, (C$_2$H$_5$O$_2$C)$_2$CH.CH.CO$_2$C$_2$H$_5$)$_2$; mw 318.3, crys, mp 76°, bp 200-215° (11 torrs). It was first prepd in 1884 by treating sodium ethylmalonate in ethanol with iodine, then in 1924 by reducing ethane-tetra-carboxylic acid tetraethyl ester with a seven-fold excess of aluminum amalgam for two hrs at 50-60° in 95% alc (Ref 11)

1,2-Dinitroethane-tetra-carboxylic Acid Tetraethyl Ester,
(C₂H₅O₂)₂C(ONO₂)₂.C(NO₂)₂(NO₂X(CO₂C₂H₅)₂); mw 408.32, wh crys, mp 65–66°C (Ref 2), 74–75°C (Ref 8). It was prepd by electrolysis of an 8% aq soln of C₂H₅O₂C(C≡NO₂)⁺CO₂C₂H₅; resistant to boiling alc KOH (Ref 2).

1,2-Dinitrosaethane-tetracarboxylic Acid Tetraethyl Ester, (C₂H₅O₂)₂CO₂(ONO₂).C(NO₂)₂(NO₂X(CO₂C₂H₅)₂; mw 376.32, oil; prepd by electrolysis of a soln of a mixt of (C₂H₅O₂)₂C≡NOH and its C≡NON₃ salt (Ref 3).

**Ethane-tetracarboxylic Acid Tetrahydrazone**, (H₂N.NHOC₂H₂.CH.CH(CONH.NH₂)₂; mw 262.2, N 42.7%, wh crys, mp 205–210°C dec, sl sol in org solvs; first prepd by Tiemann by re-fluxing 50g of the tetraethyl ester with 42g of hydrazine hydrate in alc for 2 hrs (Ref 9).

**Ethane-tetracarboxylic Acid Tetrazide**, (N₂O.C₂H₂.CH.CH(CON₃)₂; mw 306.17, OB to CO₂ 47%, N 54.9%, wh crys, expl when contacted with a flame. It was prepd from the tetrahydrazone tetrahydrochloride in alc chilled HCl by addn of aq NaN₃, at best in 25% yield and only from no more than 3g of starting material (Ref 5).

Refs: 1) Beil 2, 331–332, (699–700)

2) C. Ulpiani, O. Gasparini, Gazz 32 II, 236 (1902)

3) C. Ulpiani & G.A. Rodano, Gazz 36 II, 81 (1906) (Dinitroso)

4) H. Tiemann, "Über die Hydrazide der α-Athan tetracarbonsäure", Inaug-Dissertation, Heidelberg (1911)


6) E. Philipp & J. Hanusch, Ber 53, 1300 (1920) (Anhydride)

7) C. Mannich & E. Ganz, Ber 55, 3509 (1922)

8) F. Allsop & J. Kenner, JChemSoc 1923, 2315

9) S. Coffey, Rec 42, 399 (1923) (Hydrazide)

10) H. Staudinger & W. Kreis, Helv 6, 324 (1923) (Anhydride)

11) E. Philipp & R. Seka, Monatsh 45, 273–9 (1924) (Ester)

12) A. Michael & J. Ross, JACS 55, 3693 (1933)

**Ethane-tetraurethane and Derivatives**

Ethane-tetraurethane, called Acetylene-tetraurethane in Ref 4; (called Athanetetraurethan or 1.1.2.2-Tetrakis [carboxy-amin]-ăthan, in Ger), (C₂H₅O₂)₂C(ONO₂)₂.C(NO₂)₂(NO₂X(CO₂C₂H₅)₂; mw 378.38, N 14.81%, wh ndls (from abs alc), mp 260°C dec (Ref 6), 268°C (Ref 2), 276–78°C (Ref 7), 268–87°C (Ref 5), subl 240°C (0.2 torr), sol in alc and in ether (Ref 2), insol in alc, dioxane, hexane (Revs 3, 5, & 7). It was first prepd by Curtius (Revs 1 & 2) by refluxing an ether soln of 1,1,2,2-Ethane tetracarboxylic acid Tetrazide with abs alc; later prepd by refluxing at 100°C a mixture of ethyl carbamate, 30% aqueous glyoxal and hydrochloric acid, in 49% yield (Revs 3, 5 & 7); most recently prepd by refluxing glyoxal hydrate with ethyl carbamate and boron trifluoride etherate in benz., in 68% yield (Ref 7). Ref 7 states that the compd is incorrectly identified in Ref 3 as C₂H₅O₂CN.CH.CH.NCO₂C₂H₅. CA 25 (1931) Subject and Formula Indices for Ref 3 list the compd as C₂H₅O₂CN.CH.N.CO₂C₂H₅ and Ref 5 agrees with Ref 3.

Sadtler Standard Spectra, Midget Edition 1″, Sadtler Research Labs, Philadelphia, Pa (1962), No 3888 agrees with CA, and Ref 6 agrees with Ref 2 but gives no reasons. Neither of Revs (3, 5, 7) appears to be aware of Revs (1, 2).


3) H. Pauly & H. Sauter, ChemBer 63, 2068 (1930)

4) ADL Synthesis HE's, 2nd Rept (1951), pp 51 & 53 (Gives incorrect Vol and p of Ref 2)

5) N.G. Gaylord, JOC 20, 546 (1955)

6) BASF FrP 1128263 (1957), ChemZtr 130, 1605 (1959)

7) P.M. Quan, JOC 33, 3937–38 (1968)

**Ethane-tricarboxylic Acid and Derivatives**

**Ethane-tricarboxylic Acid or Metrol (Mrz), (Athān-tricarbonsäure, in Ger),**

HO₂C.CH₂.CH.CO₂H₃; mw 162.1, OB to CO₂ 74%. This subst is listed as a parent compd for the triazide, although it was not used to prep it. It was, however, used for prep of its triinitrate.

**Ethane-tricarboxylic Acid Triazide**, N₂O.C₂H₂.CH.CH(CON₃)₂; mw 237.14, N 53.15%; viscous oil, expl violently on heating; prepd by Curtius by treating hydrazide diammonium of ethane-tetracarboxylic acid with HCl, followed by NaN₃.

Refs: 1) Beil 2, 812 & (681) (parent); 2, 321 (triazide)


**Ethane-1,1,1-tris(hydroxymethyl)Triinitrate**

(Popularly called Metrol Trinitrate (MrT), also, variously Methyltrimethylolmethane Tri-
nitrate, Nitropentaglycerin, Pentaglycerol Trinitrate, Methyl-tris(hydroxymethyl) methane Trinitrate, CH₃(CH₂ONO₂)₃; mw 255.16, NO₂ 54%, N 16.47%, OB to CO₂ ~34.5%; heavy, colorless, odorless oil with flat taste; fr p ~60°, sp gr 1.4685 at 20/4°, dp 1.4760 at 17.5°, nD 1.4748 at 25°. Sp mass given as 1.451 (Ref 8). Solubility is 0.5g/l in w.

Accdg to Refs 1a & 8a, MtrT was de
dveloped in Italy before WWII by Bombmri-Parodi-Delfino and then adopted by the Germans.

The following method of prep was used during WWII at the Krümmel Fabrik of Dynamit AG:

a) 50kg of finely pulverized metritol was slowly fed with stirring by means of a worm screw into a stainless steel nitrator containg 175kg of mixed acid (65% HNO₃ - 35% H₂SO₄) maintained at 20°C. Formation of lump was avoided because this could lead to overheating and decomp of metritol and acid

b) After 20 mins of nitratation, 15 mins were allowed for separation of the oil from acid

c) The separated oil was washed, first with warm water, then with soda ash soln and finally with water. The temperature during all the washings was maintained at 40°C because at a low temp the mixture was too viscus. The soda ash wash lasted 20 mins. The yield was 200 parts of MrT per 100ps of Mr

d) The washed oil was taken to a storage tank from which it was withdrawn when needed for prep of "Robpulvermasse" (raw paste), serving for prep of proplnts (See Note, below)

Ger technical MtrT was a heavy oil, practically insol in w, with N=16.00 to 16.32%, sp gr 1.460 at 20°C, stability by Abel Test at 82°C - 20 mins, decomp temp ca 182° impact sensitivity with 2kg hammer 4cm, calorific value 1270kcal/kg (water in liq phase) and volatility less than for NG. It was used in some smokeless proplnts and as a replacement for NG

Note: Robpulvermasse, Raw Propellant Mass or Rawpaste was a mixture of water-wet NC with an exp oil, such as MrT NG, DEGDN, TEGDN, etc. Such wet mix was safely transported when a smokeless propellant plant was not located adjacent to the plants manufg NC and organic nitric esters. Prep of Rob-
pulvermasse and of propellants as practiced during WWII at Krümmel and Dunneberg Plants of Dynamit AG is described in Refs 1a, pp 6, 10 & 65 and in Ref 8a, p 169

Other props of purified Metrilo Trinitrate: impact sensitivity 0.59kg/m for 50% deton

(Ref 2). Dipole moment 3.39D at 25°C (Ref 10). Vapor pressure over 26-72°C given by Clausius-Clapeyron eqn: log p = A-B/T where A = 14.6237, B = 4603.4; calc'd heat of vaptz given as 21kJ/kg (Ref 11). Stability towards alk hydrazine given as: sp rate of hyd = 6.9x10⁻⁴M/sec, at 30°C in 90% alc (v/v) with 0.08-0.15M NaOH (Ref 13). Min film thickness for propagation of HV deton (7100m/s) given as 0.16 inch, for LV deton (1500m/s) given as 0.01 inch (Ref 14). It was prep'd from the alcohol with nitric acid at 10°C in 90% yield, with nitric-sulfuric acid at 10°C in 93% yield, and with nitric-sulfuric acid at 70°C in 98% yield (Ref 2); also from the alcohol with 98% nitric acid in glacial acetic acid at RT in 90% yield (Ref 4). Infrared spectrum (Refs 5 & 9) shows the three major peaks at 6.04, 7.87 and 11.9µ. Addnl drop weight test data given in Ref 3. Heats of expnl and formation given in Ref 7. Gap sensitiity given in Ref 12; patented for use with 1,3-diol-2,2-dimethyl-pentane dinitrate as main expl ingredients in a commercial blasting agent (Ref 6)

E 154

& CA 62, 8923e (1965) 12a) Urban'ski 2
(1965), p 197-98 (1,1,1-Trimethylolthane
Trinitrate)  13) R.T.M. Fraser, Chem & Ind
1968, (33), 1117-18 & CA 69, 78867 (1968)
14) J. Ribovich, AnnNYacAdSci 1968, 152(1),
766-72 & CA 70, 69726 (1969)  15) W.L.
Schwowyer, USP 3461007 (1969) & CA 71,
93221 (1969)

ETHANOL AND DERIVATIVES

Ethanol, Etbyedi, Ethyl Alcohol or Alcohol
(Alcohol in Fr, Alkohol in Ger and Alkogol' in
Rus), CH₃CH₂OH; mw 46.07, colorless liq.,
sp gr 0.879 at 20°/4, fr p -114.5°, bp
78.4°, fl p of 95% alc 14°C (57°F), heat of
combustion 327.6 kcal/mole and heat of for-
amation -66.4 kcal/mole, miscible with w,
eth, methanol & chl; sol in many other org
solvents. It is a good solvent for many expls
and its mixture with eth dissolves NC of
12%N. Alcohol can be derived from ethylene
either by direct catalytic hydration or by
means of ethyl sulfate as an intermediate.
It can also be obt'd as a by-product of hydro-
carbon synthesis from CO and H₂, and as a
by-product of methanol synthesis from these
gases. The oldest method of alcohol prep
is by fermentation of grains, molasses and
carbohydrates. It can also be prep'd by fer-
mntation of sulfite pulp. Alcohol prep'd from
gains is known as grain alcohol and it is used
in prep of beverages (Refs 1, 11 & 12)

The strength of alcohol commonly used in
the US is 95% (190 proof), while 96% is used in
Europe. For prep of perfumes the 70% alcohol
is used. The so-called absolute alcohol (200
proof) is at least 99% and its use is restricted
to analytical purposes or research. The so-
called industrial alcohol is unfit to drink be-
cause it contains up to 5% methanol (wood
alcohol) or benzene. Such alcohol is known as
denatured and it is briefly described in
Vol 3 of Encycl, p D63-R. Denatured alcohol
is used as a solvent for expls, rocket fuels,
rubbers, detergents, etc. Mixture of 1 part
alcohol with 2 parts eth (described in Vol 5
of Encycl as Diethyl Ether) used as a solvent in
dehydration of Pyocellulose in manuf of
single-base prop. In, such as described in
Davis (Ref 2) and also on p C399 of Vol 3 of
Encycl, under "Colloiding Agents and Col-
loidal Propellants"

US Spec JAN-A-463B, Interim AMD 1(Mu),
22 March 1967, gives the requirements and
tests for ethyl alcohol for Ordnance use (See
below)

Stettbacher (Refs 3 & 5), who obt'd information
from Amer journal "Engineering" of
Aug 30, 1946 stated that Ger WWII 320-kg
rocket was propelled by mixture of alcohol
32.4 parts by wt and liquid oxygen 67.6 parts.
Its heat of combustion was 2020 kcal/kg and
temperature of expln 2760°C. A similar mixture
or possibly a mixture of equal parts of alcohol
and liq oxygen, which weighed 8.1 metric tons,
was used for propelling V2

In the paper published in Explosivstoffe,
Stettbacher gives thermodynamic data for al-
cohol/oxygen and alcohol/hydrogen peroxide
rocket fuels, the latter having only 1477 kcal/kg
as heat of combustion

Use of alcohol as an ingredient of liquid
rocket fuels also was described by Krop (Ref 6)
and by Warren (Ref 10)

Accdg to Grosse (Ref 9), a mixt of frozen
alcohol with liquid oxygen can be made to de-
tonate by a sharp blow with a hammer. When
alcohol was frozen in liquid air and nitrogen
allowed to boil off, leaving a mixt of alcohol
and oxygen, the residual mixture was expl

Expn of mixtures of alcohol-nitrogen
dioxide was discussed by Gray & Yoffe (Ref 4)

Protection against alcohol explns was dis-
cussed by Sauerteig (Ref 7)

Sax (Ref 13) indicates that air containing
more than 1000 parts per million of ethyl al-
cohol is irritating to the eyes and upper res-
piratory system. He rates it dangerous as a
fire or disaster hazard when exposed to heat
or flame, and moderate as an expln hazard
when exposed to flame

Refs: 1) Beil 1, 292, (146) & (281) 2) Davis
(1943), 299-305  3) Stettbacher (1948), 52-3
4) P. Gray & A. Yoffe, JCS 1950, 3183-84 &
CA 46, 26 (1952)  5) Stettbacher, Pálvoara
(1952), 68 
6) S. Krop, JetPropulsion 24, 224
(1954)  7) H. Sauerteig, Brannweinwirtschaft
77, 138-43 (1955) & CA 49, 9278-79 (1955)
8) A. Stettbacher, Explosivstoffe 1956, 25 &
29-30  8a) Sax (1957), 247 
9) A. V. Grosse,
(1961), pp 457-R & 458-L  12) Kirk & Othmer,
2nd ed, Vol 8 (1965), p 422 
13) Sax, 3rd ed
(1968), p 733
Use of Ethanol and Ether in the Manufacture of Single-Base Smokeless Propellants. Operations in manuf. of single-base smokeless propellants from Pyrocellulose, which is NC of N content 12.60±0.10% (described in Vol 2 of Encycl, p C103) are discussed in Vol 3 of Encycl, under "Colloidal Agents and Colloidal Propellants" on pp C398 & C399. Manuf. of NC is described in Vol 2, p C102, while its stabilization for use in smokeless propellants is described in Vol 2, p C107

Specification requirements and tests for ethanol used in manuf. of propellants are in MIL-E-463B with Interim AMD 1 (MU), March 22 1963. This Spec is discussed as next item

Specification requirements and tests for ether, given in MIL-E-199A(1), are discussed in this Vol under Ether, Diethyl, whereas its prepn and props are given in Vol 2, pp D1233–D1235, under Diethyl Ether.

A good description of manuf. of single-base propellants, including four illustrations, is given in Davis (1943), pp 299 to D306

Note: During the dehydration procedure described in Vol 3, p C399-L, it is required to determine ethanol and water in the cylindrical block removed from the press. In these dets a piece of block (cake) is dried in an oven at 100° to obtain "total volatile content", the water is detd by Karl Fischer Method and then alc is obtd by difference. Finally ether is added to make a colloid mixture contg 2 parts of ether to 1 part alcohol by wt. The above tests are described in the items which follow.

Ref: N.M. Liszt, private communication, Oct 1972

ETHANOL, Analytical Procedures

The section described below was compiled in collaboration with Mr N.M. Liszt, Analytical Chemistry Branch Chief, Propellants Lab, FRL, Picatinny Arsenal.

Ethanol, US Military Specification MIL-E-463B (14 May 1962), entitled Ethyl Alcohol (For Ordnance Use) requirements and tests, supplemented by Interim Amendment 1 (MU) 22 March 1967

1.1 Scope. This Spec and Amd 1 cover the requirements for six grades of ethyl alcohol intended for Ordnance Use.

1.2 Classification. Ethyl alcohol shall be of the following grades:

- Grade 1 – 95% by volume without denaturant
- Grade 2 – 94.9% by vol with denaturant
- Grade 3 – 99% by vol (anhydrous) with benzene denaturant
- Grade 4 – 95% by vol denatured with tertiary-butyl alcohol and benzyl diethylcarbamoyl ammmonium benzoate
- Grade 5 – 95% by vol (See 3.1.5)
- Grade 6 – 88.3% by vol (See 3.1.6)

2.1 Applicable Documents – Listed among them are:


3. Requirements

3.1 Material. Ethanol, prior to the addn of dye or denaturant, shall be a clear, transparent, colorless liquid, having a characteristic odor, and shall not contain visible insoluble material, either before or after the addition of dye or denaturant. Table Et 1 lists compositions of alcohols intended for Ordnance uses

3.1.1 Applicable to Grade 1. It shall contain neither dye nor denaturant

3.1.2 Applicable to Grade 2. It shall be made by the addn of benzene to alc that complies with the requirements of Grade 1, or that has been recovered from the manufg operation in which it will be used

3.1.3 Applicable to Grade 3. It shall be made by the addn of benzene to an anhydrous grade (99%) of alc contg neither dye nor denaturant

3.1.4 Applicable to Grade 4. It shall be made by the addn of 1/8 gage of tert-butyl alcohol and 1/4 avoirdupois ounce of benzyl diethylcarbamoyl ammonium benzoate to 100 gals of ethyl alcohol that complies with the requirements of Grade 1. It shall be dyed with 1 part by wt of fuchsin dye to 500,000 parts by wt of alcohol

3.1.5 Applicable to Grade 5. It shall be made by mixing 100 gals anhydrous (99%) alc with 5 gals anhydrous methyl alcohol

3.1.6 Applicable to Grade 6. It shall be made by mixing 100 gals of Grade 5 alc with 5 gals of ethyl acetate and 1 gallon of methyl-isobutyl ketone
### Table Et 1

<table>
<thead>
<tr>
<th>Components</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
<th>Grade 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl alcohol, % by vol, min</td>
<td>95.0</td>
<td>94.9</td>
<td>99.0</td>
<td>94.9</td>
<td>95.0</td>
<td>88.3</td>
</tr>
<tr>
<td>Benzene, % by vol, max</td>
<td>0.01</td>
<td>0.75</td>
<td>0.75</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Acidity, g/100ml as acetic acid, max</td>
<td>0.005</td>
<td>0.01</td>
<td>—</td>
<td>—</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Aldehydes, mg/100ml, max</td>
<td>20.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Non-volatile matter, % max</td>
<td>0.004</td>
<td>0.006</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Organic impurities, % max</td>
<td>0.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Methyl alcohol, % by vol, max</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Ethyl acetate, % by vol, max</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.4</td>
</tr>
<tr>
<td>Methyl-isobutyl ketone, % by vol, max</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.3</td>
</tr>
</tbody>
</table>

3.2 Chemical and Physical Requirements.

Alcohols shall comply with the requirements shown in Table Et 1, when detd as specified in the applicable sub-paragraph of 4.3

3.3 Taste. Grade 4 alcohol shall be distinctly bitter.

4. Quality Assurance Provisions, which include:

4.1 General Quality Assurance Provisions
4.1.1 Contractor Quality Assurance System
4.1.2 Submittal of Product
4.1.3 Government Verification
4.1.3.1 Surveillance
4.1.3.2 Product Inspection
4.2 Inspection Provisions, which include:
4.2.1 Lot Formation
4.2.2 Examination
4.2.3 Testing
4.2.3.1 Sampling
4.2.3.1.1 Containers
4.2.3.1.2 Tank Cars

are discussed on pp 3–5 of Spec MIL-E-463B

4.3 Test Methods and Procedures

4.3.1 Ethyl Alcohol Content. Determine specific gravity at 15.6/15.6°C (60/60°F) by means of a calibrated hydrometer, pycnometer or other standard method. Calculate the percentage of alcohol by volume from Table 2, attached to Spec MIL-E-463B

Note: Tables given in Lange and ChemRubberCo cannot be used because they are not as detailed in the range of 93.0 to 100% alcohol by volume (See also GasChromatographic Method of USI, described under 4.3.9 Ethyl Acetate)

4.3.2 Benzene Content. The test for benz in Grade 1 alcohol shall be made by the colorimetric method 4.3.2.1 and the tests for benz in Grades 2 and 3 alcohol shall be made by the spectrophotometric method 4.3.2.2 or 4.3.2.3

4.3.2.1 Colorimetric Method for Benzene Determination. In this method it is necessary to run simultaneous tests for three alcohols: Grade 1 alcohol (sample), Grade 1 95% alcohol contg 0.01% benzene (serving as a standard) and the blank consisting of 95% alcohol contg no benzene. All three of them must be treated in the same manner, as follows:

Mix in a 50ml beaker, (placed in an ice water bath) slowly, with mechanical stirring, 5 ml of white fuming nitric acid (contg no brown fumes) with 5ml concd sulfuric acid (sp gr 1.84), taking care not to allow the temp to go above 25°. Add from a small buret, dropwise, to the vigorously stirred and cooled mixed acid, 0.5ml each of the above mentioned alcohols from their own burets and pour the resulting mixture slowly into 40ml of cold water contd in the 2nd beaker, provided with a mechanical stirrer and placed in an ice water bath. The temp in the 2nd beaker shall not go above 25°. Transfer the mixture to a 125ml separatory funnel, add 20ml diethyl ether and shake cautiously for 1 min. Discard the lower layer.

Add to the ether extract (contg Nitrobenzene, if any benzene is present) in the funnel 20ml distd water and shake for about 1 min to remove the bulk of residual acid. Discard the lower layer and add to the ether layer a 20ml soln, made by diluting 5ml of satd Na bicarbonate soln with 15ml of distd w. Shake and, after allowing the separation
of layers, remove the lower one carefully into clean beaker. Test the soln in the beaker with a universal indicator test paper for alkalinity. If the soln is acid, repeat the washing with fresh 20ml bicarbonate soln and test it as above. It must be alkaline, which is indicated by yellow to yel-brownish color.

Discard both washings and transfer ether layer thru the mouth of the separatory funnel to a dry 50ml beaker. Rinse the funnel with about 10ml ether and run it into the same beaker.

Place the beaker on a steam bath and evaporate the ether extract to near (but not complete) dryness. Cool the beaker and rinse its contents with 10ml benzene-free 95% ethanol into a dry test tube (16 by 150mm). Add 1 ml of butanone (methyl ethyl ketone), shake and add 0.5ml dilute alcoholic NaOH soln, which was previously prepared by diluting 1 volume of aqueous NaOH soln (40g NaOH per 100ml distilled water) with 10 vols of benzene-free 95% ethanol. Mix thoroughly and allow to stand for 5 minutes before testing it colorimetrically. The color of blank contg no benzene must be yellow to yellow-orange, while the color of “standard” contg 0.01% must be reddish. If the color of sample is not of greater reddish intensity than the standard, it is considered satisfactory.

**4.3.2.2 Spectrophotometric Method for Benzene Determination.** This method is based on the fact that benzene has a characteristic absorption curve in the ultra-violet region. It is used for testing Grades 2 & 3 alcohols, each contg 0.75% benzene.

**4.3.2.2.1 Apparatus.** Absorbance measurements shall be made using a spectrophotometer with ultra-violet accessories, matched 1 cm silica cells and a blue sensitive phototube in position. A Beckman Model DU Spectrophotometer has been found to be satisfactory.

**4.3.2.2.2 Standard Curve.** Prepare standard solns of benzene in ethyl alc by pipetting 0.2, 0.5 and 0.8ml of reagent grade benzene respectively into labelled 100ml volumetric flasks. Dilute benz in each flask to the mark with benzenefree, reagent grade benzene (95% or absolute) and mix the solns. Pipet from each flask 10ml portions to three other 100ml vol flasks, respectively, dilute the solns in these flasks with reagent grade methanol and mix thoroughly. Take the absorbance readings of these solns at a wave-length of 261 milli-

microns using a methanol blank. Plot the absorbance readings against the concentration, and this should be a straight line passing thru the origin. Record all pertinent data and retain the graph for use with the particular instrument in future routine work after checking two points on the curve.

**4.3.2.2.3 Spectrophotometric Procedure.** Pipet a 10ml portion of the sample to a 100ml volumetric flask, dilute to the mark with reagent-grade methanol and mix thoroughly. Fill one of the silica cells of the apparatus with the sample soln, whereas the 2nd cell is filled with pure methanol. Insert the cells in the cell holder and, after proper adjustment of instrument, take the reading at 261 millimicrons, while using a slit width chosen for best sensitivity. Read the quantity of benzene in the sample from the standard curve prepared in par 4.3.2.2.

**4.3.2.3 Alternate Method for Grade 2 and 3 Alcohols.** Micropipet a 0.10ml portion of the sample to a dry test tube and add by means of a small pipet 5ml concd sulfuric acid contg 0.5% of formaldehyde soln which is not weaker than 37%. After shaking the tube, compare its color with that of a 0.10ml portion of alcohol contg 0.75% benzene and treated in the same manner as the sample. The color developed in the tube with sample shall not be darker than that developed in alc contg 0.75% benz. In case of question, doubt, or dispute, the spectrophotometric method described above shall be mandatory.

**4.3.3 Acidity.** Mix 100ml of sample with 100ml of freshly-boiled distilled water (free of CO₂), add 2 drops of bromothymol blue indicator (0.04% LaMotte or Taylor solns) and titrate with 0.01N Na hydroxide soln to a blue end-point. Calculate the acidity as acetic acid as follows:

\[
\text{Acetic acid in g/100ml = 0.06VN,}
\]

where: \( V = \text{ml of alkali used} \)
\( N = \text{normality of alkali} \)

**4.3.4 Aldehydes (Preparation of Sample).** Transfer 120ml of alcohol sample to a 250ml Erlenmeyer flask, add about 20ml of distilled water and a few drops of carbontandom. Distill slowly into a 100ml volumetric flask to the mark, and mix.

**4.3.4.1 Aldehydes (Procedure).** Transfer the above freshly distilled alcohol from the 100ml volumetric flask to a 500ml flask, add about
100 ml distd w and excess of 0.05N Na bisulfitite, which is equivalent to approx 25 ml of 0.05N iodine soln. After allowing to stand for about 30 mins with occasional shaking, add excess 0.05% N iodine soln and titrate this excess with 0.05N Na thiosulfate soln. Run a blank using the same quantities of 0.05N iodine and Na bisulfite as used in the sample. Calculate as follows:

Aldehydes, in mg/100 ml = A x 1.1
where: A = difference in ml between the titrations of sample and blank of Na thiosulfate soln used

4.3.5 Nonvolatile Matter. Evaporate 100 ml of the sample on a steam bath in a tared dish (preferably platinum) and dry the residue to constant weight in an oven, maintained at 105 to 110°C. The increase in weight of dish shall be calc as percentage non-volatile residue. Calculate as follows:

Nonvolatile matter in g/100 ml = B - A
where: A = tare wt of dish
B = wt of dish with residue

4.3.6 Organic Impurities. Prepare a standard soln by pipetting 0.1 ml portion of reagent grade, isomethyl alcohol (isobutyl-carbinol) into 100 ml volumetric flask and making up to the mark with reagent grade absolute alcohol. Both of the following, on this standard soln, and on the sample, shall be conducted using test tubes of uniform size. These tests are especially intended for the detection of an excessive percentage of fusel oil in alcohols 4.3.6.1 Sulfuric Acid Method for Organic Impurities. Place 10 ml of the sample in a large test tube and run sulfuric acid of sp gr 1.84 cautiously, with swirling, down the side of the test tube. The temp of the soln will rise to about 90°C. Place in an identical test tube 10 ml of the standard soln and treat in the manner described above. Place both test tubes in an oven or bath at 65° for 18 hours and compare the colors developed in solns. The development of a definitely darker color in the sample than in the standard soln shall be cause for rejection 4.3.6.2 Potassium Permanganate Method for Organic Impurities. Place in one of the two identical test tubes 10 ml of the sample, while in the other tubes are placed 10 ml of the standard soln of par 4.3.6. Adjust the temp in each tube to 25±0.2° and add to each tube one drop of soln contg 1 g K permanganate per liter of distd w. Record the time and wait. Complete fading of the pink color in sample soln in less than 10 mins indicates the presence of more than 0.1% organic impurities. There shall be almost no pink color in the standard soln after standing for 10 mins. Note: Fusel oil can also be detd by the method 4.6.1.6 of Interim FedSpec O-E-00760C(TR-1R), which is as follows: Mix 10 ml of alcohol to test with 5 ml of distd w and 1 ml glycerin(USP) and allow to evaporate spontaneously from clean, odorless absorbent paper. The sample shall be considered as having passed the test if no foreign odor is perceptible when the last traces of alcohol evaporate 4.3.7 Water. Determine the percentage of water by wt in accordance with ASTM Method D1364-64. This method covers the dem of w. in any proportion in volatile solvents (such as alcohol and ethyl acetate). It is not applicable in the presence of mercaptans, peroxides and appreciable quantities of aldehydes and amines. Although the ASTM method is similar to Karl Fischer method described in Vol 5 under DYNAMITE, to the method described in Bobbs Manual and to the Method 101.5 of MIL-STD-286B, it differs from them in some details. For this reason the ASTM method is described here.

To determine water, Fischer reagent (a soln of iodine, pyridine and sulfur dioxide in the molal ratio of 1:10:3) dissolved in anhydrous ethylene glycol monomethyl ether is added to a soln of the sample in anhydrous pyridine-ethylene glycol (1:4) until all w present has been consumed. This is evidenced by the persistence of the orange-red end point color; or alternatively by an indication of a galvanometer or similar current indicating device which records the depolarization of a pair of noble metal electrodes. The reagent is standardized by titration with water a) Instrument End Point for this test is that point in the titration when two small Pt electrodes, upon which a potential of 20 to 50 mv has been impressed, are depolarized by the addn of 0.05 ml of Fischer reagent (6 mg of water per ml), causing a change of current flow of 10 to 20 μA which persists for at least 30 sec. b) Color End Point. During the titration, the
soln first turns yellow, then deepens and the end point is indicated by the sharp change to orange-red. This color must persist for at least 30 secs in order to indicate an end point.

**Apparatus**

a) **Titration Vessel.** For color end point titrations, use a 100- or 250-ml volumetric flask fitted with interchangeable electrodes (Fig Er 1). The same flask may also be used for instrument end point and is particularly suitable for titrations at ice temps. For permanently mounted assemblies, the vessel should have a capacity of about 300 ml, be provided with a tight-fitting closure, a stirrer, and a means of adding sample and reagents and removing spent reaction mixture. Such flasks are made by Rankin Glass Blowing Co, Martinez, Calif. It is desirable to have a means for cooling the titration vessel to ice temp (Fig Er 1).

b) **Instrument Electrodes** are of platinum with surface equivalent to two No 26 wires 3/16 inch long. The wires should be 3 to 8 mm apart and so inserted in the vessel that 25 ml of liquid will cover them.

c) **Instrument Depolarization Indicator** having an internal resistance of less than 5000 ohms and consisting of a means of impressing and showing a voltage of 20 to 50 mv across the electrodes and capable of indicating a current flow of 10 to 20 μA by means of a galvanometer or radio tuning eye circuit, similar to the "Aquatrator" of Precision Scientific Co, shown in Fig 5 and described in Vol 5 under DYNAMITE, "General Methods of Analysis Applicable to Commercial Blasting Explosives Including Dynamites" or "Fisher Titrimeter", described in catalogs of Fisher Scientific Co, Pittsburgh, Pa.

d) **Buret Assembly** for Fischer reagent, consists of a 25- or 50-ml buret connected by means of glass (not rubber) to a balloon containing the reagent. Several types of automatic dispensing burets are on the market. Of these, the type similar to Catalog No J-821 of Scientific Glass Co, Bloomfield, NJ or Catalog No 750 of Eck & Krebs, NY, has been specifically designed for this analysis and presents the minimum contact of reagent with stopcock lubricant. One of such burets: "Macklett Automatic Burette" is shown in Fig 4 under DYNAMITE.

Since the Fischer Reagent loses strength when exposed to moist air, all vents must be protected against ambient moisture by means of drying tubes containing Indicating Drierite™.

All stopcocks and joints should be lubricated with materials not particularly reactive with the reagent, such as Apiezon N (James G. Biddle & Co of Phila, Pa); High Vacuum Silicone Grease (Dow Corning Co, Midland, Mich); or Sisco 300 (Swedish Iron & Steel Co, New York, NY).

**Reagents:**

Unless otherwise indicated, it is intended that all reagents conform to the specs established by the Committee on Analytical Reagents of the ACS, where such specs are available; otherwise the best available grade must be used.

a) **Fischer Reagent** (1 ml equivalent to 6 ml of 12 in 425±2 ml anhydrous (less than 0.1% water) pyridine in a dried glass stoppered bottle. Add 425±2 ml anhydrous (less than 0.1% water) ethylene glycol monomethyl ether, cool to below 4°C in an ice bath and introduce in the solution gaseous sulfur dioxide, dried by bubbling through concd sulfuric acid (sp gr 1.84). Determine the amount of sulfur dioxide added by measuring the loss in weight of the sulfur dioxide cylinder (102±1 g).
Alternatively, add 70 ml of freshly drawn liq sulfur dioxide in small increments

b) Sample Solvent. Mix 1 vol of anhydrous (less than 0.1% water) pyridine with 4 vols of anhydrous (less than 0.1% water) glycol and keep it in a glass-stoppered bottle

Note: If adequately dried reagents cannot be procured, they can each be dried by distillation through a multiple-plate column, discarding the first 5% of material distilling overhead and using 95% remaining.

c) Standardization of Fischer Reagent. Standardize it daily by either the color or instrument end point method, proceeding as follows:

Add 25 ml of the above "sample solvent" to titration flask of Fig Et 1 and titrate with Fischer reagent to orange-red end point. Add to the solvent, thus titrated, instead of the sample, 0.15 to 0.18 g distd w from a weighing piper. Complete the titration with Fischer reagent as described below under "Titration of Sample"

Calc the equivalence factor of the reagent by means of the following equation:

\[ \text{Equivalency Factor, } F = \frac{A}{B} \]

where:

A = mg H₂O added to "sample solvent", and
B = ml of Fischer reagent required for titration

d) Titration of Sample

It is essential to avoid changes in water content of the material during sampling operations. Errors from this source are particularly significant in the analysis of materials having low water or having the tendency to readily absorb moisture, such as absolute alcohol.

It is necessary to limit all possible contact of the sample with air in transferring the sample into the titration vessel

Procedure:

Introduce 10 to 25 ml of the anhydrous "sample solvent" (pyridine-glycol, 1:4) into the titration vessel (Fig Et 1), making sure, if an instrument end point apparatus is used, that the electrodes are covered by the amt of "sample solvent" introduced. If the color end point is also to be used, introduce 10 to 25 ml sample into the 2nd titration flask

Adjust the stirrer to provide adequate mixing without splashing and titrate the mixture in the 1st flask with Fischer Reagent to the instrument end point, while the 2nd flask is titrated from the 2nd buret to the orange-red color end point

To each of the flasks add an amount of sample accdg to its water content, as follows:

25 ml if water is assumed to be below 0.5%,
10 ml for 0.2 to 2.5% water content and 0.15 to 0.18 g sample for 2.5 to 10% water content

Continue titration of the 1st flask to the instrument end point, while the 2nd flask is titrated to the color end point

Calculation:

\[ \text{Water Content, } \% = \frac{V \times F}{10 \times W} \]

where:

V = ml of Fischer Reagent required for sample
F = equivalence factor for Fischer Reagent, in mg of water per ml of Reagent, and
W = weight of sample in grams

4.3.8 Methyl Alcohol. The test is listed but not described in MIL-E-463B, but the following description is given in Interim Federal Specification, O-E-00760C (TR-I), August 7 1970 under Test 4.6.1.5 on pp 6–7

Preparation of Reagents:

Potassium Permanganate Solution — 100 ml of an aqueous soln contg 15 ml of 85% phosphoric acid and 3 g of potassium permanganate. Renew reagent every 4 weeks

Chromotropic Acid Solution. A 5% aqueous soln of the acid (1,8-dihydroxyxanaphthalen-3,6-sulfonic acid) or its Na salt

Procedure for Determination of Methyl Alcohol. Dilute a portion of the alcohol sample with distd w to make the ethanol content 5 to 6%.

Pipet 2 ml of the permanganate soln into a 50 ml volumetric flask, chill in an ice bath, add 1 ml of the diluted alc sample and allow to oxidize in the ice bath. Decolorize the oxidized sample with a small amt of dry Na bisulfite and add 1 ml of the chromotropic acid reagent. Rotate the flask with a swirling motion, while adding by pipet 15 ml of concd sulfuric acid, and place the flask in hot water (60–70°C) for 15 mins. Remove the flask, cool to RT and make up to 50 ml with distd w. Compare the color of the soln with that of a standard (95% ethanol, contg 0.1% methanol), which was subjected to the above procedure. The sample passes the test if the depth of purple color is less than that of the standard. If the color is less than light straw, no methanol is present (See also Gas Chromatographic Procedure of USI described under 4.3.9 Ethyl Acetate)

4.3.9 Ethyl Acetate. The test is listed but not described in MIL-E-463B. It is stated that "ethyl acetate content shall be determined by using a suitable method that has been approved
by the contracting officer". As such statement does not help to solve the problem, we asked Mr N.M. Liszt to try to get the description of the method. He was able to obtain it thru the courtesy of Mr Michael Toto, Office Manager of US Industrial Chemical Co, NY 10016, who communicated the method to Mr Anthony Taschner of Picatinny Arsenal. The method is gas-chromatographic and is used by Industrial Chemical Co for dem of Ethyl Acetate, Ethyl Alcohol, Methyl Alcohol and Methyl-iso-butyl Ketone (MBK). General procedure for gas chromatography is described in Vol 3 of our Encycl, pp C293-R & C294-L. Following is outline of method used by USI

A quantitative gas chromatographic method for the denaturants in filmex C can be made under the following conditions:

- Instrument – Varian Model 2800 chromatograph
- Detector – Flame ionization
- Attenuation – As noted on chart
- Sample size – 1 µl
- Range – 10⁻¹⁰ amps/mv
- Column – 6' x 1/8” Chromosorb 102
- Program – Start 140°C, hold for 4 min; heat at 10°C/min to 195°C and hold
- Run is complete in 23 minutes

Calculation – Compare peak areas (or peak heights) of the unknown to those of a standard of similar composition to determine quantitative results

Figure shows a typical chromatogram of filmex C run under the above conditions.

The Chromosorb column will give good separation of the components under various temperature programs. The initial temperature can be below 100°C to give a wider peak for methanol if a high count integrator is not available. If desired, an internal standard can be used. Under the conditions described, benzene can be used.

A suggested procedure would be equal volumes of the sample and a 4% (by volume) benzene in pure ethanol. This is easily set up using a G.C.-Computer system.

Note: Ethyl Acetate can also be detd by Standard Method ASTM Designation D1617-69, described here under Ethyl Acetate.

4.3.10 Methyl-isobutyl-ketone (MBK). The test is listed but not described in MIL-E-463B, but it seems that the Test 4.6.1.8 for determination of Acetone and other ketones, described
in Interim Fed Spec O-E-00760C (TR-IR), 7 Aug 1970 can be applied here

Procedure: To 1 ml of the alcohol to test, add 4ml of distd w and 10ml of mercuric sulfate test soln (Denigès Reagent), prep'd by mixing 5g of yellow mercuric oxide with 40ml distd w, followed by 20ml concd sulfuric acid, added slowly with stirring. Finally 40ml of distd w are added and the mixture is stirred until complete soln is attained. Then the soln is heated on a bath of boiling water and, if no ppt appears within 2 mins, the sample is considered as having passed the test. (See also Gas Chromatographic Procedure of USI, described under 4.3.9 Ethyl Acetate)

5.1 Packing. Ethanol shall be furnished in 5-gallon or 55-gallon metal containers as described on pp.10 and 11 of Spec MIL-E-465B

6.1 Intended Use:
Grade 1 - For use in the manuf of MF (Mercuric Fulminate), Smokeless Propellant (where a denaturant is not required), small arms primers, and optical elements

Grade 2 - For use in the manuf of Smokeless Propellant, ether, ethylene, and shellac mixtures

Grade 3 - For use in shellac mixtures for ammunition

Grade 4 - Denatured alcohol for general use where the grade in Federal Spec O-E-760 is not suitable for use

Grade 5 and Grade 6 are used in the mixing and manufacture of pyrotechnics (N.M. Liszt of Picatinny Arsenal; private communication)

Note: Benzylidethyl(2,6-xylencarboxyl) ammonium benzoate may be purchased from Walker Chemical, Inc, 22 West First St, Mount Vernon, NY or other source

Ethanol Determination by Estimation of Its Hydroxyl Group, Using Various Esterification Procedures

Following methods are described in Std-MethodsChemAnalysis 2A(1963), pp 455–460:

Esterification with Acetic Anhydride, Method 1:
Uncatalyzed Reagent. It is based on the following reaction:

\[
\text{C}_2\text{H}_5\text{OH} + \overset{O}{\text{CH}_3\text{COO}} \rightarrow \text{CH}_3\text{COO} - \text{C}_2\text{H}_5 + \text{CH}_3\text{COOH}
\]

and is described on pp 455–59

Esterification with Acetic Anhydride, Method 2:
Reagent Catalyzed with perchloric acid is described on pp 456–57. It is more rapid than Method 1

Esterification Using Phthalic Anhydride is described on p 458

Esterification Using Pyromellitic Dianhydride is described on pp 458–59. This method combines the advantages of esterification by acetic anhydride and by phthalic anhydride

In the same book, on p 462 is described "Colorimetric Method for Determining Trace Quantities of Hydroxy Compounds". This method developed by V.W. Reid & R.K. Trulove and described in Analyst 77, 325 (1952) uses cetic ammonium reagent and is applicable to determinations of small quantities of alcohol in aqueous or water miscible systems [Compare with J. Lamond, Analyst 74, 560–61 (1949), listed here as Ref 5, under "Ethanol, Ether, Acetone and Water Determinations in Solvents Used in Manufacture of Smokeless Propellants, as Described in the Literature"]

Ethanol, Ether and Water Determination in Single-Base Propellants by US Army Munition Command Method T103.5 entitled: Total Volatiles, Gas Chromatographic Method. The method is described in MIL-STD-2688, 30 June 1971

1. Scope

1.1 This method is based on extraction of the solvents from the propellant with a mixture of predried methyl ethyl ketone and secondary butyl alcohol (25/75% by volume). The method is directly applicable to propellants containing N of about 13.15% N. By controlling the ratio of extracting solvents, propellants containing N lower than N content (such as 12.60 or 12.00% N) can be analyzed by this procedure. For such propellants, a lower MEK to sec-BuOH ratio should be used to prevent complete dissolution

2. Specimen

2.1 The specimen shall consist of approx 10g of the propellant with minimum atmospheric exposure in order to reduce loss of volatiles or adsorption of water. This procedure has been used successfully on the following single-base propellants using original size: M-1 SP, M-1 MP, Benite, IMR & CBI and gunpowder M-6. It should be applicable to other single-base formulations. The specimens are cut to convenient size as specified in Method 509.3, entitled Preparation of Propellant Samples, described in MIL-STD-286B (1 Dec 1967). This
method is used for prep g sheet and granular propellant for analysis. It is warned that procedures involving grinding should not be used for propellants containing potentially hazardous oxidants, such as chlorates and perchlorates

**Apparatus:**
- a) Laboratory Mill (Wiley, Standard Model No 2C, or equivalent), equipped with a shield and an explosion-proof motor, Class 2
- b) Beryllium alloy shears or razor blade;
- c) Powder cutter (modified paper cutter, preferably with beryllium blade) and
- d) Glass bottle, stoppered

**Procedure for Sheet Propellant.** Cut sheet into pieces approx 1/8-inch square, using razor blade or shears. Place cut pieces immediately in a glass bottle and stopper it

**Note:** If grinding is specified, make the propellant brittle by chilling it in an ice bath prior to grinding as described for small grain propellant

**Procedure for Small Grain Propellant.** Prepare the mill for grinding propellant (of size 0.2g or less) by placing the 20-mesh screen betw the grinding chamber and the receiving container, and firmly clamp the rotor cover plate in position. After placing the shield in proper position, start the motor and grind few grains at a time, checking the temp of machine betw grindings. Place ground sample immediately in the bottle and stopper it. Allow sufficient time for the rotor and blades to cool before grinding addl portions of propellant

**Procedure for Large Grain Propellant.** Cut grains larger than 0.2g into slices approx 0.17mm thick, using the power cutter. Cut these slices into pieces approx 1/8-inch square and place them immediately in the bottle and stopper it

3. **Apparatus for Method T103.5**
3.1 Gas chromatograph (GC) equipped with a thermal conductivity detector and a one-milliamp recorder and/or integrator (or equivalent)
3.2 Column: eight-foot stainless steel, 1/4-inch outer diameter containing 80–100 mesh Porapak Q
3.3 Erlenmeyer flasks, 125ml
3.4 Rubber stoppers, size 5/8, solid
3.5 Syringe, 50 microliters
3.6 Flow meter, 10cc
3.7 Serum bottles, 30ml
3.8 Rubber stoppers for serum bottles
3.9 Pipets, 25 and 50ml, volumetric
3.10 Shaker, horizontal (for flasks)

4. **Materials for Method T103.5**
4.1 Acetone, reagent grade
4.2 Methyl ethyl ketone (MEK), certified reagent grade (Fisher Scientific Co, No M209, or equivalent)
4.3 Sec-butyl alcohol, reagent grade (Eastman Organic Chemicals Cat No 943 or equivalent)
4.4 Molecular sieves, type 4A, size 1/16 inch pellets
4.5 Ethyl alcohol, absolute, dried
4.6 Water, distilled
4.7 Diethyl ether, reagent grade, dried
4.8 Helium, commercial grade
4.9 Extraction soln, mixt of dry MEK 25 with dry sec-BuOH. It must be kept stored in contact with molecular sieves to keep dry

5. **Procedure for Method T103.5**
5.1 Preparation of Extraction Solvents
a) Dry solvents for extraction by addg approx one-inch layer of molecular sieves directly to the gallon containers of MEK and sec-BuOH prior to mixing in proper ratio and allowing 2 days for the sieves to absorb the moisture
b) Mix MEK and sec-BuOH in 25:75 ratio and add one-inch layer of molecular sieves to the container

5.2 Preparation of Standard
a) Piper 25ml of the dry mixed solvent into a tared 30ml serum bottle
b) Stopper the bottle, weigh it with soln to the nearest 0.2mg and label
c) Using a syringe, inject thru the rubber stopper 0.10ml each of distilled water, dry ethanol and ether, reweighing the bottle after each injection to the nearest 0.2mg. Be careful not to get any of the liquids on the stopper during injections
d) Record the wt of each component in the standard

5.3 Testing
a) Add approx 10g of propellant, weighed to the nearest 0.2mg, to a 125ml Erlenmeyer flask and stopper immediately
b) Label the flask and record the wt of propellant in it
c) Pipet 50ml of 25/75-MEK/BuOH solvent into the Erlenmeyer and immediately stopper it. Solvent must sufficiently cover the sample and if it does not, as with CB1 propellant, addnl amt of solvent must be added
d) Place the tightly stoppered flask on the horizontal shaker at low speed and ambient condition for gentle shaking to swell the propellant and extract volatile solvents from it
e) Extraction times are 2 hours minimum for M-1 SP, M-1 MP, Benite, CBI & IMR and 6 hours minimum for crushed M-6
f) Remove the flask from the shaker and allow 15 mins for settling the larger part of the solids

% Water = \frac{(AB-\text{FG})(W_1)(100)(E)}{(CD-\text{FG})(W_2)}

% TV (Total Volatiles) = \% Alcohol + \% Ether + \% Water

where:

A = Attenuator setting for unknown sample (alcohol, ether or water)
B = Area of peak for unknown sample (alcohol, ether or water)
C = Attenuator setting for standard (alcohol, ether or water)
D = Area of peak for standard (alcohol, ether or water)
E = Ratio of solvent between sample and its standard (equals 2 when 50ml is used for sample and 25ml is used for standard)
F = Attenuator setting for water in the extraction solvent
G = Area of peak for water in the extraction solvent
W_1 = Grams of component per 25ml of standard
W_2 = Sample weight (10g)

Ethanol + Ether, as "Residual Solvent"

Determination in Single-Base Propellants

(US Ordnance Methods). Determine the percentage of total volatiles (Solvents + Moisture), then of moisture and subtract percentage of moisture from percent of total volatiles to obtain residual solvent.

For determination of Total Volatiles (Volatiles and Moisture), two methods can be recommended:

I. Vacuum Oven Method 101.1.2, Described in MIL-STD-286B (1 Dec 1967), is applicable to single-base, small-grain, proplints

Procedure:

a) Tare to within 0.2mg a weighing dish, 30mm diam and 30mm deep together with a tight-fitting cover and place in it approx 10g sample of proplint
b) After reweighing the dish with the sample, uncover it and place for 6 hours in a vacuum oven maintained at temp 55±2°C and a pressure (absolute) of 80±10mm of mercury
c) Cool the dish with sample to RT in a desiccator (contg an indicating desiccant), replace the cover and reweigh the whole

Calculation:

% Total Volatiles = \frac{(W_1-W_2)(100)}{W_1}
where:

\[ W_1 = \text{Weight of sample before drying} \]

\[ W_2 = \text{Weight of sample after drying} \]

Note: This method is also briefly described in StdMethods of ChemAnalysis, Vol 2, Part B (1963), p 1294

1. Scope

1.1 This method is used for determining the total volatiles content of either single-base, double-base, or triple-base propellants.

2. Specimen

2.1 The specimen shall consist of approximately 2g of the propellant prep'd with minimum atmospheric exposure in order to reduce loss of volatiles.

3. Apparatus

3.1 Solution tubes (Fig Et 3)

3.2 Steel balls, 5/16-inch diam.

3.3 Tubing, rubber, 5/16-inch bore, 3/16-inch wall.

3.4 Vacuum line assembly (Fig Et 4)

3.5 Wire screen tray (Fig Et 5)

---

**FIG Et 3** SOLUTION TUBE

**FIG Et 5** WIRE SCREEN TRAY

**FIG Et 4** VACUUM LINE ASSEMBLY
3.6 Protective drying tubes (Fig Et 6) containing indicating desiccant
3.7 Vacuum pump capable of maintaining a pressure (absolute) of at least 5mm of mercury
3.8 Wire holders for solution tubes (Fig Et 7)
3.9 Counterpoise (Fig Et 8)
3.10 Pyrex glass wool, or equivalent
3.11 Oven containing a rocking device with evacuation manifolds (Central Scientific Co, Cat No 95105-A modified by addition of a safety latch, or equivalent)
4. Material
4.1 Dibutylphthalate, prepared as follows:
a) Dissolve 1 g of diphenylamine in 100 ml of hot dibutylphthalate
b) Pour this solution into 500 ml of dibutylphthalate; stir vigorously
c) Add dibutylphthalate to make 1 liter; stir vigorously
d) Heat the solution for 2 hours at 145° to 150°C while bubbling dry air thru it
Note: The heating ensures that the solution will lose less than 10 mg in 50 ml during the solution-evacuation procedure, and may be omitted if previous tests show that it is unnecessary.

5. Procedure
5.1 Prepare at least four solution tubes (two for the specimens, two for blanks) as follows:
a) Place 10 clean, dry, steel balls and 50 ml of the dibutylphthalate reagent into each solution tube
b) Clean the inlet of each solution tube with absorbent cotton held by steel forceps, and insert a wad (approx. 0.2 g) of pyrex glass wool, using the forceps
Caution: Position the glass wool at such a point in the tube that it will not fall into the tube and will not touch the cork stopper that is to be inserted subsequently.

5.2 Precondition the solution tubes as follows:
a) Using 5 cm pieces of the rubber tubing, connect the solution tubes to the manifold of the rocking device in the oven, placing the tubes containing the blanks at opposite ends of the manifold. Plug or otherwise close unused manifold connections.
Note: New connecting tubing should be pre-cleaned by boiling in a 5% solution of sodium hydroxide for 10 to 15 mins, followed by a thorough rinsing, and drying at 100°C.
b) Connect the vacuum line assembly (Fig Et 4) to the manifold of the rocking device and to the vacuum pump
c) On the vacuum line assembly (Fig Et 4), open stopcock A; close stopcocks B & G and needle valve E; and set stopcock F to connect the manifold to the vacuum pump
d) Adjust the oven temperature to 85±1°C, start the rocking motor, and turn on the vacuum pump. Evacuate the tubes at a pressure of 5 mm or less for 1½ hours.
e) At the end of 1½ hours, stop the vacuum pump and rocking motor, and slowly open stopcock B. Then slowly admit dry air to the solution tubes by gradually opening needle valve E.
Caution: If the air is admitted too rapidly, wads of pyrex wool may be drawn into the solution tubes.
f) Wearing gloves, remove the solution tubes from the oven, leaving the connecting tubing attached to the tubes, and place them in the wire-screen tray (Fig Et 5). Immediately attach a protective drying tube (Fig Et 6) to the inlet of each solution tube to prevent the admission of atmospheric moisture. Allow the tubes to cool to room temperature (approx 45 mins).
g) When the solution tubes have cooled, remove the protective drying tubes and connecting tubing, and insert No 1 cork stoppers.
Caution: The solution tubes must be kept tightly corked hereafter to prevent absorption of atmospheric moisture by the very dry dibutylphthalate, except during evacuation in the oven and while being weighed.

5.3 Clean and remove electrostatic charges from the solution tubes by wiping them with a wet towel and drying them with a clean lint-free cloth (without rubbing). Place the tubes in the wire-screen tray, cover them with a cloth to protect them from dust, and allow them to stand near the balance for at least 30 mins to attain equilibrium with the moisture content of the air.
Caution: After the tubes have been conditioned, they should not be touched with the fingers until they have been weighed. When handling the tubes, grip the inlet tube only, after covering the inlet with a tissue paper.

5.4 Cut sheet and large grain proplnt as described in Method 509.3, paragraphs 4.1 and 4.3, respectively. Use small grain proplnt as received. Take at least two specimens.

5.5 Remove the cork stoppers from two of the prepared solution tubes, and take out the wads of glass wool, using forceps. Add one of the accurately weighed specimens of the proplnt to each, using a small metal funnel (9 mm O.D. outlet) to prevent adherence of the proplnt to the walls of the tube. Reinsert the wads of glass wool.
Note: Proplnts soften and tend to gelatinize when added to dibutylphthalate solution. Therefore, the solution tubes should be rocked as soon as possible after the addition so that
the propellant does not adhere to the walls of the tube and prevent the steel balls from moving 5.6 Support the tubes in wire holders (Fig. Et 7) and weigh each solution tube (incl. blanks) to within 1 mg, using the counterpoise (Fig. Et 8) on the right-hand side of the balance. 

Note: The counterpoise approximates the weight, volume, and exterior surface area of a solution tube containing 10 steel balls and 50 ml of dibutyl phthalate. It should be kept standing near the balance, covered with a cloth to protect it from dust. Do not wipe the counterpoise; wiping will disturb its equilibrium with the prevailing temperature, pressure, and humidity.

5.7 Shake the tubes, if necessary to loosen any grains of propellant adhering to the walls of the tubes, and connect the tubes to the manifold of the rocking device in the oven. Plug all unused manifold connections.

5.8 As soon as all the solution tubes have been placed in the oven (maintained at 85°±1°C), start the rocking motor.

5.9 On the vacuum line assembly (Fig. Et 4) check that stopcock F is turned so that nitrogen does not enter the vacuum line. Then open the valve on the nitrogen cylinder to allow a slow stream of nitrogen to escape thru the mercury trap.

5.10 Close stopcocks B & G, and needle valve E, and open stopcock A. Then turn on the vacuum pump, and evacuate the soln tubes to a pressure of 1 mm of Hg or less.

5.11 When the pressure has stabilized at 1 mm of Hg, turn stopcock F to admit nitrogen slowly to the soln tubes. 

Caution: Admit nitrogen slowly so that the glass wool or other foreign matter from the manifold or tubing is not carried into the soln tubes.

5.12 Evacuate the tubes again, and refill with nitrogen by operating stopcock F.

5.13 Turn stopcock F so that the nitrogen inlet is connected to the oven manifolds, open stopcock G to admit air to the vacuum line, and turn off the vacuum pump. Close stopcock G.

5.14 Allow the soln tubes to rock until sample has completely broken up or a max of 15 hours at a temp of 85°±1°C.

5.15 At the end of 15 hours, check that stopcock G is closed, and turn stopcock F to connect the oven manifolds to the vacuum pump. Open stopcock B and needle valve E, and start the vacuum pump.

5.16 While observing the soln tubes thru the glass door of the oven, gradually close needle valve E to lower the pressure in the vacuum line assembly, being careful not to close the valve so fast that the soln in the tubes boils violently.

Caution: Take approx. 10 mins to lower the pressure to 5 mm of Hg. If the soln boils violently, there is danger of mechanical loss of the soln, and a resulting error in the determination.

5.17 When the pressure reaches 5 mm, or less, close stopcocks A & B, and continue the evacuation for 2 hours at 85°±1°C, and at a pressure of 5 mm of Hg or less.

5.18 At the end of 2 hours, stop the rocking motor, open stopcocks A & B, very slowly open needle valve E to admit dry air, and stop the vacuum pump.

Caution: If stopcock A is not open when the vacuum pump is shut off, the dibutyl phthalate soln will flow out of the pressure regulator.

5.19 Remove the soln tubes from the oven, and cool them, as described in paragraphs 5.2(f) and 5.2(g).

5.20 Condition the tubes as described in paragraph 5.3.

5.21 Weigh the tubes, as described in paragraph 5.6 to determine the loss in weight of the tube containing the specimens, and the change in weight of the tubes containing the blanks.

5.22 Calculate the percentage of total volatiles in each of the 2-gm specimens using the equation given below. The results of calculations must agree to within 0.10%. If not, repeat the analysis.

Percent total volatiles = \[ \frac{100(A + B)}{W} \]

where:

A = Decrease in weight of specimen tube
B = Change (average) in weight of blank tubes taken algebraically
W = Weight of specimen in grams

Note: The change in wt of the blank tubes usually is a decrease and the value substituted for B becomes a negative quantity. However, in some instances it is an increase (possibly as a result of humidity changes) and then the value substituted for B becomes a positive quantity. The blank values must agree with in 2 mg. If not, the analysis must be repeated.

For determination of Moisture in single-base propellants, three methods can be used:

1. Scope

This method is used for determining the moisture content of small grain or flake proplnts. Single, double or triple base proplnts can be used. The principle of the method is measurement of the current required for electrolysis of water that has been volatilized from the specimen. Volatile compounds such as alcohols, amines and ammonia may also be electrolyzed. Comps that polymerize may eventually inactivate the cell.

2. Specimen

2.1 The specimen shall consist of a 0.2–0.6g sample of proplnt weighed to the nearest 0.2mg.

3. Apparatus

3.1 Solids moisture analyzer (Consolidated Electrodynamics Corp, 360 Sierra Madre Villa, Pasadena, Cal, or equivalent) (See Fig Et 9)

4. Materials

4.1 Nitrogen, extra-dry grade, in a cylinder with a pressure regulator to supply gas at 5psig.

For calibration of the instrument, use accurately weighed samples of either 0.05 or 0.1 g of sodium tartrate dihydrate or 0.3 to 0.5g of potassium tartrate hemihydrate. On drying for 45 mins at 150° C, the sodium salt should give a moisture content of 15.66±0.05% while the potassium salt should give a moisture content of 3.83±0.02 percent.

5. Procedure

5.1 Prepare the instrument for operation according to the manufacturer's directions.

5.2 Place the weighed specimen in the sample boat, insert into the oven with the aid of tweezers provided with the instrument and close the oven.

Caution: These steps must be done as rapidly as possible in order to minimize changes in moisture content.

5.3 Turn the temperature and timer controls to the settings required in the applicable spec. When the test is completed, read the wt of the moisture shown on the dial and convert to grams.

\[ \text{Percent of water} = \frac{100A}{W} \]

where:
\[ A = \text{Weight of water shown on dial, g} \]
\[ W = \text{Weight of specimen in grams} \]

**FIG Et 9  BLOCK DIAGRAM OF ELECTROLYTIC HYGROMETER**
II. Moisture Determination in Propellants and Explosives by Distillation Method 102.1.3, Prescribed by MIL-STD-286B (1 Dec 1967). Although this procedure is similar to the one described under Dynamite in Vol 5, p D1620-R, we are describing it because it uses trichloroethylene (in lieu of carbon tetrachloride) as a solvent and a 100g (in lieu of 50g) sample. The same type of moisture tube (of Hercules Powder Co) is used in both cases (See Fig 1, p D1621-L in Vol 5)

1. Scope

1.1 This method is used for the determination of moisture content of small grain or finely divided cannon propellant. It is based on distillation of the moisture with a solvent that is immiscible with and heavier than water. Trichloroethylene is the preferred solvent, but carbon tetrachloride is also satisfactory. This method is not suitable for propellants containing less than 0.2% moisture. The presence of hydrated compds may cause high results. The presence of finely divided aluminum may cause a reaction with the chlorinated solvent and, in such cases, tests should be made to demonstrate compatibility of propmt and solvent

2. Specimen

2.1 The specimen shall consist of approx 100g of the propmt preferably as received. Weigh the specimen to within 10mg

Note: If the size of the propmt as received would unnecessarily prolong the time required for the determination, the specimen may be cut as specified in Method 509.3. The cutting, weighing, and transferring to the stoppered balloon flask must be done rapidly to minimize the change in moisture content thru exposure to the atmosphere

3. Apparatus

3.1 Balloon flask, 500ml
3.2 Condenser (Allihn type, or equivalent), 400mm long (min)
3.3 Drying tube containing indicating calcium sulfate desiccant
3.4 Moisture tube (Kontes Glass Co, Cat No K-75500, or equivalent)

Caution: If ground glass joints are used, be sure that no propmt is in the joints before making the connection

3.5 Hot plate (preferably steam or hot water heated)

4. Materials

4.1 Solvent: Trichloromethylene (preferably) or carbon tetrachloride

5. Procedure

5.1 Place the specimen in the 500ml balloon flask, and add 200ml of the solvent
5.2 Fill the graduated portion of the moisture tube with the solvent, and attach the tube to the flask. Attach the moisture tube to a dry condenser, and connect the drying tube containing the desiccant to the top of the condenser to keep out atmospheric moisture
5.3 Heat the flask so that the distillate falls from the condenser at the rate of two to three drops per second. Continue the distillation for the time indicated in Table E2
5.4 Remove the source of heat, and wash the water from the condenser into the moisture tube with 10ml portions of the solvent until the volume of the water layer in the measuring tube becomes constant, and no water droplets are observed in the condenser

Note: A total of 30 to 50ml of the solvent is usually required

5.5 Read the lower part of the top meniscus. Read the upper part of the lower meniscus

Note: To facilitate the reading of the menisci, the surface of moisture tube and the condenser may be made water repellant by treatment with a suitable silicone preparation, such as Desicote (Beckman Instruments Inc). If water repellant material is used, read the point of contact of the top meniscus with the wall of the tube and the center of the lower meniscus

5.6 Determine the difference in the readings, and record the difference as the volume of water in the specimen

5.7 For each lot of solvent run a blank using exactly 2ml of water and apply any necessary corrections to the sample

5.8 Considering one ml of water as equal to one gram, calculate (by weight) the % of moisture in the specimen

\[
\text{Percent water} = \frac{A - B}{W} \times 100
\]

where:
A = Upper meniscus, ml
B = Lower meniscus, ml
W = Weight of specimen in grams
Table Et 2

<table>
<thead>
<tr>
<th>Propellant web size, inch</th>
<th>Grain condition</th>
<th>Distillation time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.025</td>
<td>Whole</td>
<td>3</td>
</tr>
<tr>
<td>0.025 to 0.040</td>
<td>Whole</td>
<td>5</td>
</tr>
<tr>
<td>0.041 to 0.060</td>
<td>Whole</td>
<td>10</td>
</tr>
<tr>
<td>0.061 to 0.090</td>
<td>Whole</td>
<td>16</td>
</tr>
<tr>
<td>Over 0.090</td>
<td>Sliced</td>
<td>8</td>
</tr>
</tbody>
</table>

III. Moisture Determination in Propellants and Explosives by Karl Fischer Method 101.5, Prescribed by MIL-STD-286B (1 Dec 1967). Detailed description of Fischer method as applied to various substances is given in the following works:

3. Vol 5 of this Encycl, under DYNAMITE
5. ASTM D1364–64 (Reapproved 1970), "Standard Method of Test for Water in Volatile Solvents" (Fischer Reagent Titration Method)

Following is the description of Method 101.5 of MIL-STD-286B:

1. Scope
1.1 This method describes the materials, equipment, and procedures for determining the percentage of moisture in casting solvent, casting powder, casting powder ingredients, and case propellant by the Karl Fischer (KF) method (manual and semi-automatic titrations). This procedure is designed for water contents of less than 1%.

1.2 Limitations and Interferences. The Karl Fischer reagent is composed of pyridine, sulfur dioxide, and iodine dissolved in either methanol or ethylene glycol monomethyl ether. Substances which react with any of these components will interfere. For example, Karl Fischer reagent will react with aldehydes or ketones in the presence of methyl alcohol. Other examples of interfering substances are oxidizing agents such as peroxides, cupric and ferric salts; reducing agents such as sodium thiosulfate, sodium arsenite, stannous salts and hydrazine; and oxygenated compounds such as metal hydroxides and oxides, bicarbonates and carbonates, and boric acid.

2. Specimen
2.1 Care must be taken that all samples are protected from gain or loss of water before testing. Propellant samples must be reduced in size to about 1/8-inch cubes to readily dissolve in the solvent. The mode in which this is done is left to the discretion of the installation as it is a function of sample stability and general safety.

3. Apparatus
3.1 Aquameter (Beckman Instruments, Inc, Model KF2 or KF3 or equivalent. Equivents are described in ASTM E203-62T)
3.2 Titration Flask, protected from atmosphere with provisions for electrodes and burets
3.3 Magnetic Stirrer
3.4 Buret, 10ml capacity, 0.02ml divisions

4. Material
4.1 Karl Fischer Reagent, single solution stabilized, methyl cellulose as solvent, eg, catalog No So-K-3, diluted to about 2mg/ml titer with methyl cellulose or a commercial diluent, eg, catalog No So-K-5 of Fisher Scientific Co

4.2 Solvents
Pyridine-Methanol 1:1; mix equal volumes of reagent quality of each solvent containing less than 0.10% water. This must be maintained in a protected system.

4.3 Standards
a) Sodium Tartrate Dihydrate, ACS grade containing 15.66% water
b) Water – distilled or equivalent

5. Calibration and Standardization
5.1 The water equivalent (mg water/ml KF reagent) is obtained by titrating weighed amounts of a standard with the KF reagent as follows:
5.1.1 Add about 50-100ml of the solvent to the titration flask. Maintain a dry nitrogen purge in free volume of container. Using the procedure described in the instrument instruction manual, or the routine procedure for the manual titrating assembly, titrate to a potentiometric end point which remains for 30 seconds. By means of a Lunge pipette, syringe, or equivalent, add one drop of water to the titration flask. Record to the tenth of a milligram the weight of water added, fill the
burette again, and titrate to a 30 second potentiometric end point. Alternately, 200mg of sodium tartrate dihydrate may be added instead of water and may be titrated in like manner. Record the volume of reagent used for the titration.

5.1.2 The water equivalent is obtained by dividing the number of milliliters used into the weight of water added. If sodium tartrate dihydrate was added, the calculation is as follows:

Water Equivalent (mg H₂O/mlKF reagent) =

\[
\frac{(mg\ sodium\ tartrate\ dihydrate) \times 0.1566}{ml\ of\ KF\ reagent\ required}
\]

5.1.3 The titer should be about 2mg/ml. If too high or low adjust concentration and restandardize.

5.1.4 Frequent standardization is necessary as the reagent is unstable.

6. Procedure

6.1 Accurately weigh a sample large enough to give a minimum titration of 3ml (5-7ml is desirable).

6.2 Add 50-100ml of the solvent used to the titration flask and titrate to a 30 second end point.

6.3 Maintain a dry nitrogen purge over free volume of the flask.

6.4 Add the sample, stir until in solution and titrate to a 30 second potentiometric end point. Note: Some samples require about 1 hour to dissolve. Flasks must be well protected to insure water is not absorbed from atmosphere.

6.5 Calculation

Percent water = \( \frac{AF}{1000W} \times 100 \)

where:

A = ml Karl Fischer Reagent used to titrate sample
F = Karl Fischer titer in mg water/ml reagent
W = Sample weight in grams

Ethanol, Ether, Acetone and Water Determinations in Nitrocelluloses and Smokeless Propellents as Described in the Literature:

1) L.A. Chenel, MP 22, 143-44 (1926) & CA 22, 166 (1928) (Determination of water and ethanol in dehydrated NC was carried out at the Laboratoire Central des Poudres by heating a 7-10g sample in a special U-tube in a glycerol bath for 24-30 hours, while the dry air was drawn thru the tube into two tared absorption tubes. The 1st tube contd dry K₂CO₃ pumice to absorb water, while the 2nd contd sulfuric acid pumice to absorb alcohol. After weighing the tubes, the passing of air thru the tube with sample was repeated for 6 hours and the absorption tubes reweighed. If no increase in wt was observed the test was regarded as completed).

2) L.A. Chenel, MP 23, 4-6 (1928) & CA 22, 3531 (1928) (Detn of alcohol, ether and water in solvent eliminated from propellant during drying).


Note: More recent description is given in Ref 6 and in StdMethodsChemAnalysis 2A (1963), pp 455-57.

4) B.E. Christensen et al, IEC (AnalEd) 13, 821 (1941) (Determination of hydroxyl group by esterification with pure acetyl chloride, Problems of volatility and activity of reagent are surmounted).


6) C.L. Ogg et al, IEC (AnalEd) 17, 394 (1945) (Determination of hydroxyl groups by esterification using acetic anhydride in presence of pyridine).

Note: This method, as well as other methods for det hydroxyl groups, are described in StdMethodsChemAnalysis 2A (1963), pp 455-59.


Note: This method is described in StdMethodsChemAnalysis 2A (1963), p 458.

8) T.G. Bonner, Analyst 72, 47-54 (1947) (Estimation of Ethanol and Ether in Propellants which Might Also Contain Acetone, and Other Ingredients (such as camphor, diphenylamine, dibutylphthalate, diethylphthalate and diphenylurea)).

Procedure:

A. By means of a steel pestle and mortar, crush the propellant sample into pieces of about 3mm across, weigh accurately 2-3g and add it to 25ml of nitrobenzene contd in 250-ml, 3-neck flask. The middle neck of the flask is provided with a gas-tight stirrer, the 2nd neck with a reflux condenser and the 3rd neck with a tube to
bubble the air thru the flask. Connect the upper end of the reflux condenser to three special, spiral absorption tubes connected in series.

Notes:

a) The soln in the 1st tube is intended to oxidize ethanol, while allowing ether, acetone and camphor to pass unchanged. The soln is prepd by mixing in a 100-ml volumetric flask 25ml of aqueous soln contg exactly 8g of K$_2$Cr$_2$O$_7$ per liter, plus 2.5ml of concd H$_2$SO$_4$. The soln is transferred but not completely to the 1st tube, while the flask is retained without rinsing it, because the soln will be eventually returned to it.

b) The soln in the 2nd tube is intended to remove acetone and camphor which are present in some propmts. Acetone and camphor being not oxidized in the 1st tube, are oxidized in the stronger soln of the 2nd tube. This soln is prepd by boiling gently in a 2-liter, one-neck flask, under reflux for 10 hours, 104g of KMnO$_4$ and 261g of KOH in one liter of water. After allowing to cool, the supernatant soln is poured off and kept in a stoppered bottle. A 30-ml portion of it is used to fill the 2nd absorption tube.

c) The soln in the 3rd tube serves to oxidize the ether. It is prepd by mixing, with cooling, in a 200-ml volumetric flask 25ml of an aq soln contg exactly 16g of K$_2$Cr$_2$O$_7$ per liter with 25ml of concd sulfuric acid. After pouring the bulk of this soln in the 3rd absorption tube, the flask is retained without rinsing, as the soln is eventually returned to it.

B. Stir the nitrobenzene soln of sample in 3-neck flask vigorously and with flask immersed in hot water bath, pass a stream of air thru the soln at the rate of 1-2 bubbles per second for 5 hours.

C. Stop the flow of air, wash the dichromate solns of tubes 1 and 3 back into their respective volumetric flasks and make up to the marks with water.

D. Pipet out 25ml from the 1st flask and add it with cooling and stirring to about 30ml of 10% aq KI soln. After 2 minutes, dilute with water to about 100ml and titrate the liberated iodine with 0.05N of Na$_2$S$_2$O$_3$ soln using starch indicator. Calculate the amt of ethanol oxidized in the 1st tube knowing that 1g of K$_2$Cr$_2$O$_7$ corresponds to 0.0234g of ethanol.

E. The 2nd solution is present to oxidize acetone, camphor, etc which otherwise would get into the 3rd tube, be oxidized, and introduce an error in the ether determination.

Note: A determination of acet in propmts is given by Bonner in Analyst 72, 434-439 using an extraction method to separate the acetone and an iodine thiosulfate method to measure the acetone.

F. Pipet out 25ml from the 3rd flask and add it with stirring and cooling to about 100ml of 10% aq KI soln. After 2 minutes, dilute with water to about 200ml and titrate the liberated iodine with Na$_2$S$_2$O$_3$ soln. Calculate the amount of ether, knowing that 1g of K$_2$Cr$_2$O$_7$ corresponds to 0.1886g of ether.

9) G. Fleury & H. Liogier, "Dosage du Dissolvant Résiduel dans les Poudres B", MP 30 223-28(1948) [Estimation of Ethanol and Ether in Propellants in Absence of Acetone or Ethyl Acetate]

Following is the method developed at the Poudrerie Nationale de Saint Médard before WWII but described only in 1948.

Briefly, the method is based on the following operations:

a) Saponification of propmt by Na hydroxide soln.

b) Separation of alcohol and ether based on the great difference between their vapor pressures in the neighborhood of RT and on the solubility in water of alcohol and of insolubility of ether.

c) Estimation of amounts of separated alcohol and ether by K dichromate in strong sulfuric acid medium.

Apparatus, presented in Fig Et 10 consists of the following items:

A - Bubbler, contg concd sulfuric acid (or K dichromate soln in it), serving to count the number of bubbles of air entering thru stopcock R$_2$ and to retain any gas or vapor which might adversely affect the analysis.

B - Round bottom flask, called "un ballon de saponification".

C - Ascending condenser, syst Vigreux (40-45cm long) connected in series with.

D - Descending condenser of the same syst and length, which joins at its bottom to a tube provided with three-way stopcock R$_3$, which can be communicated either with:

E - Volumetric flask of 200ml, or

F - Bubbler, syst Mayer, consisting of 10 bulb, which joins to:
G – Bottle of 10 liters, filled with water and connected at the bottom to the stopcock R₁. The water slowly dripping from the bottle during the test permits maintaining in apparatus a slight vacuum of 50–60 cm of water, which prevents the escape of alcohol and ether from apparatus during the test.

Procedure. It may be subdivided into the following operations:

Saponification: Place 50 g sample of proplum in flask B containing 500 mL of aq NaOH soln of 12°Bé (about 8%) and at the same time fill the bubbler F with exactly 50 mL of 1.6N K dichromate soln in concd sulfuric acid. Close stopcock R₂, open R₃ to communicate D with F and slightly open R₁ in order to create a small vacuum in the system. After admitting cold tap water to circulate thru the condensers, start to heat the flask B to the boiling point of NaOH soln in order to saponify the proplum contd in the flask. After saponification is achieved (which usually takes about 1/2 hours), continue light boiling in B and start to admit air by opening R₂ to such an extent that about 100 bubbles per minute will go thru A. Continue light boiling and bubbling the air until about 1.5 l of water will be replaced in bottle A by air. This takes from 3/4 to 1/2 hours of time. During the continued heating and bubbling of air, vapors of alcohol and water will be condensed in C and fall back into the flask B, but vapors of ether will pass thru C and become condensed in the descending condenser D. Then liquid ether will go thru R₃ to bubbler F, where it will be partly oxidized by dichromate soln to form acetic acid.

Separation of alcohol. Turn the stopcock R₃ toward volumetric flask E, and stop circulation of cooling water thru condenser C, while continuing to cool the condenser D. This will permit the alcohol to be distilled, pass thru C to D to be condensed in it together with water, into the flask E. After collecting about 150 mL of distillate in E, filter it into another 200 mL volumetric flask (to remove DPhA) and complete to the mark with distd w
Determination of alcohol. Transfer quantitatively 50ml of previous alcohols to into Erlenmeyer flask, incline it at 45° and pour slowly on the side of the flask, with cooling and swirling, 40ml concd sulfuric acid, followed by 30ml of 1.6N K dichromate soln in sulfuric acid. Heat on the steam bath for 20 mins. in order to oxidize alc to acetic acid. Cool to RT, add KI soln and titrate the liberated iodine by means of N/10 Na thiosulfate soln using starch indicator.

Determination of ether. Transfer one-half (25ml) of dichromate soln from bubbler F into an Erlenmeyer flask, add about 20ml concd sulfuric acid, heat on a steam bath for 20 mins, cool to RT, add KI soln and titrate the liberated iodine by means of N/10 Na thiosulfate soln using starch indicator.

10) J. Tranchant, MP 35, 305–06(1953) [Determination of alcohol and ether in propellants, in presence of acetone and ethyl acetate combines the method of T.G. Bonner described here as Ref 6 with the method developed at the Fournierie Nationale de Saint Médard and described by G. Fleury & H. Fleury in MP 30, 223–28(1948)] (See our translation given as Ref 6)


Note: This method is described in StdMethodsChemAnalysis 2A, pp 456–57


Note: This method is described in StdMethodsChemAnalysis 2A(1963), pp 458–59

Ethanol, Ether, Acetone and Water Determinations in Solvents Used in Manufacture of Smokeless Propellants, as Described in the Literature:

1) M. Marqueyrol & E. Goutal, MP 19, 368–80 (1922) & CA 17, 3656(1923) (Analysis of mixtures of alcohol, ether and water can be made by determining the density of the sample in its original condition and after the addition of measured quantity of water until the liquid becomes turbid. Enclosed in the paper are triaxial diagrams, which help to make necessary calculations)

2) W.M. Fischer & A. Schmidt, Ber 57, 693–98 (1924) & 59, 679–82(1926) (Determination of ethanol or methanol by means of Na nitrite, followed by removal of ethyl-, or methyl-nitrite, with a current of carbon dioxide, followed by absorption of gas in concd Na bicarbonate soln. On action of KI soln in dilute HCl on the soln contg nitrites, the iodine is liberated and then the free iodine is detd by titration with Na thiosulfate, Na2S2O3)

3) N.V. Chalov & L.P. Vol’skaya, Zavodskaya-Lab 12, 286–91(1946) & CA 41, 3399–4000 (1947) (Determination of ethanol in dilute aqueous solns by a method, which is modification of the method of Fischer & Schmidt, listed here as Ref 2. Both methods are based on the conversion of alcohol to its nitrite and total time required is 20 mins. Sensitivity is as low as 0.025–0.005% and accuracy ±3%. A fairly detailed description of the method is given in the above CA)

4) N.V. Chalov, RussP 69874(1947) & CA 44, 78(1950) (Description of the same method as given in previous Ref 3)

5) J. Lamond, Analyst 74, 560–61(1949) [Small quantities of alcohol in ether may be detd after extracting it from ether by water, followed by testing the aqueous extract by means of cetic ammonium nitrate. The following reaction takes place, producing the red coordination product:

\[ \text{C}_2\text{H}_5\text{OH} + (\text{NH}_4)_2\text{Ce(NO}_3)_6 \rightarrow \text{CeOC}_2\text{H}_5(\text{NO}_3)_6 + (\text{NH}_4)_2\text{HNO}_3 \]

The intensity of red coloration produced by this reaction, which may be measured by means of a colorimeter is proportional to the amount of alcohol in ether]


7) G. Bourjol, MP 35, 197–98(1953) (Rapid method of analysis of ethanol-ether-water mix-
tures by combining density measurements with Karl Fischer's method for determination of water. Knowing these values, the contents of alcohol and in ether in the mixture may be read directly from a specially prepared triangular diagram. This method is a modification of Marquezol & Goutal's method described here as Ref 1. In his paper Boujou reviewed the method of analysis of triple mixture consisting of distillation using fractionating column in order to separate the ingredients into two fractions: ether-alcohol and alcohol-water, followed by determination of density for each fraction.

Ethanol Azido-, Nitroso- and Nitro-Derivatives, Ethanolazide, 2-(or β) Azidoethanol, 2-Azidoethyl Alcohol or 2-Triazo-1-ethanol, \( N_3-CH_2-CH_2-OH \); mw 87.08, N 48.26%, OB to CO\(_2\) -10%, col liq, sp gr 1.1435 at 24.9\(^\circ\), bp 60\(^\circ\) at 8mm & 75\(^\circ\) at 20mm; explodes when dropped on a hot plate. Its vapors are odorless, but highly toxic. It was first prepared in 1867 by Butlerow & Ossookin (Refs 1 & 2) and later by Forster & Fierz (Ref 3) by heating on a water bath for 48 hrs a mixture of equal parts of ethylenechlorohydrine and Na azide. It was also prepared and investigated by Urbanik (Ref 4) and A.D. Little (Ref 6). Blatt (Ref 5) stated that it is an explosive about one-half as powerful as TNT, insensitive to impact and unstable in storage. (See also Refs 6, 7, 8 & 9).

Refs: 1) Beil 1, 340 & (171) 2) Butlerow & Ossookin, Ann 144, 40 (1867) 3) M. Forster & H. Fierz, JCS 93, 1866 (1908) 4) T. Urbanik, IX Congr Intenl Quim Pura Aplicada 4, 428 (1934) & CA 30, 3649 (1936) 5) A.H. Blatt, OSDR 1971 (1944) (Azidoethyl Alcohol) 6) ADL, Pure Expl Compsds, Part 1 (1947), p 48 (Trautz Test value 50% PA or 55% TNT)


Ethanol Azidonitrate, 2-Azido-1-ethanol Nitrate; \( N_3-CH_2-CH_2-ONO_2 \); mw 132.08, N 42.42%, OB to CO\(_2\) -36.3%; volatile, toxic liq, sp gr 1.34, bp -20\(^\circ\), bp -20\(^\circ\); explodes at 180\(^\circ\) when heated at the rate of 25\(^\circ\)/min; gelatinizes NC; resembles NGC in its physiological and explosive properties. It was first prepared by Urbanik (Ref 4) by nitrating ethanol azide with mixed nitric-sulfuric acid. It can be prepped by treating nitrochlorohydrin (obtd by nitrating chlorohydrin) with Na azide. Azidonitrate was also prepared by Bergeim (Ref 2) who patented its use in dynamite-type expl mixtures, such as cond Azidoethanol Nitrate, NG, NGc, Na nitrate, woodmeal and Ca carbonate. Fishbein (Ref 3) reviewed its manuf and properties. A.D. Little, Inc (Ref 7) prepared it and detd some of its props. The compd was listed in Ref 5.

The following explosive props are given in Urbanik (Ref 4), Blatt (Ref 6) & ADL (Ref 7):

Impact Sensitivity - much more sensitive than NG or NGc; when absorbed on filter paper the pure liquid can be detonated with a hammer. For a 50/50 mixt with sawdust the max fall for no shots with 10-lb wt was 2 inches, while corresponding value for NGc was 5 and for NG 6 inches.

Power, by Ballistic Mortar - 141% TNT

Power, by Trauzl Test - 150% TNT (and 171% PA?)

Rate of Detonation - 1985 and 6550m/sec at sp gr 1.34


Ethanol, 2-Nitro; 2-Nitroethanol-1, 1-Hydroxy-2-nitroethane; or \( \beta \)-Nitroethyl alcohol, \( O_2NCH_2-CH_2-CH_2-OH \); mw 91.07, N 15.38%, OB to CO\(_2\) -61.5%; colorless liquid; sp gr 1.296 at 20/20\(^\circ\), n\(_D\) 1.4447 at 20\(^\circ\), bp p < -80\(^\circ\), bp 194\(^\circ\) at 765mm, 119-20\(^\circ\) at 35mm & 101\(^\circ\) at 15mm; chars without expn at 260\(^\circ\); sol in w, alc & eth. It can be prep'd in impure state by treating 1 mole ethylene with 1 mole of white concd nitric acid by the method of Wieland & Sakellarios (Refs 1, 2 & 3). The method of...
Gorski & Makarov (Ref 4) consists of treating Nitromethane with paraformaldehyde in the presence of K carbonate. Yields are 43–45%. Pure compd can be treated by treating an ethereal soln of CH₂I·CH₃OH with Ag nitrate (See also Ref 5). Its heats of combn & formation are given by Médard & Thomas (Ref 9).

Blatt (Ref 6) and ADL Rept (Ref 7) list the following props:
- Abel Heat Test at 82.2° – 3 mins (NG 10 mins)
- Friction Sensitivity – very insensitive
- Impact Sensitivity – very insensitive
- Initiation by Detonators – incomplete with No 8 Briska Detonator in Trauzl Test
- Power by Ballistic Mortar – 62% Blasting
- Gelatin, which corresponds to about 110% TNT
- Power by Trauzl Test – 106% TNT
- Thermal Stability at 120° – no brown fumes after 5 hours
- Vacuum Stability – 3.85°C in 40 hrs

Due to the fact that it easily gelatinizes NC forming a thick homogeneous mass, it could be recommended as an expl plasticizer for NC in prep of smokeless propells, if its stability were more satisfactory.

It was proposed for use as an explosive by Levy & Scaife (Ref 6a).

2-Nitroethanol forms a Potassium Derivative, K⁺(OCH₂·CH₂·NO₂)⁻, mp 150–60°C (decompn) (Ref 8).

Refs: 1) Beil 1, 339–40, (171) & (339)
1a) R. Demuth & V. Meyer, Ann 256, 29 (1890)
2) H. Wieland & E. Sakellarious, Ber 53, 207–68 (1920)
3) Naoum, NG (1928), 220
4) M. Gorski & S.P. Makarov, Ber 67, 996 (1934)
5) J.R. Johnson, "Preparation of Nitrocompounds"; ORSD 98 (1941), 19–21
6) Blatt, ORSD 2014 (1944) 6a) N. Levy & C.W. Scaife, JCS 1946, 1093 & CA 41, 2388 (1947)
7) ADL, Pure Expl Comps, Part 1 (1947), p 84
9) L. Médard & M. Thomas, MP 35, 155–73 (1953) (Heat of combn at const vol 275.8 kcal/mole)
10) V.I. Bumistrov & V.M. Bashinova, NeftpererabNeftekhim 1, 21–3 (1968) (Russ) & CA 68, 104503 (1968) (Phys props of 2-Nitroethanol)
Part 1 (1947), p 84
9) L. Médard & M. Thomas, MP 35, 156 & 172 (1953)

Ethanol, 2-Nitroso; 2-Nitrosoethan-1-ol; 1-Hydroxy-2-nitrosoethane or β-Nitrosoethylalcohol, ON.CH₂.CH₂.OH. Not found in the literature thru 1966.

Ethanol, 2-Nitrotrinitrate; 2-Nitroethanol Nitrate; 1-Nitroxy-2-nitroethane or β-Nitroethyl Nitrate, O₂N·CH₂·CH₂·ONO₂, mw 136.07, N 20.59%, OB to CO₂ – 11.7%; very volatile, toxic liquid with irritating odor; sp gr 1.408 at 18°C, mp ~ not given, bp 120–122°C at 17mm and 103°C at 15mm; decom at 185°C with evol of brown fumes and chars at 260°C; sol in w; distills with vapors of w & alc; being sl acidic, it dissolves in cold caustic alkali solns, giving a yellow color. It was first prepd in 1920 by Wieland & Sakellarious (Refs 1 & 3) from the same kind of oil as was obtd by Kekulé in 1869 (Refs 1 & 2) on passing ethylene into a mixture of conc nitric and sulfuric acid.

On distilling Kekulé oil in steam and in vacuum were obt Nitroglycol, bp 105°C at 19mm and β-Nitroethyl Nitrate, bp 120–122°C at 17mm.

The action of mixed acid on ethylene can be represented as follows:

\[
\begin{align*}
\text{CH}_2\text{NO}_2 + \text{HNO}_3 & \rightarrow \text{CH}_2\text{·NO}_3 + \text{HNO}_3 \\
\text{CH}_2\text{OH} & \rightarrow \text{CH}_2\text{·NO}_3 + \text{H}_2\text{O}
\end{align*}
\]

which proceeds simultaneously with formation of Edyleneglycol Dinitrate:

\[
\begin{align*}
\text{CH}_2\text{·NO}_3 + 3\text{HNO}_3 & \rightarrow \text{CH}_2\text{·ONO}_2 + \text{HNO}_3 + \text{H}_2\text{O}
\end{align*}
\]

The crude Kekulé oil, when freed from admixed and dissolved acid by washing with water, contd 40–50% 2-Nitroethanol Nitrate and 50–40% Nitroglycerol. On shaking the oil with very dil caustic alkalii, the Nitroethanol Nitrate is removed leaving pure Nitroglycerol. Numerous patents have been issued for processes of procuring pure Nitroglycerol from Kekulé oil (Refs 4 & 5)

2-Nitroethanol Nitrate was also obtd by the direct action of mixed acid on 2-Nitroethanol (Ref 4, p 220)

Nitroethanol Nitrate is an explosive compd,
comparable in power to NG but very insensitive to friction and impact, very volatile and of unsatisfactory stability. It easily gelatinizes Collodion Cotton

Following properties are listed in Blatt (Ref 6) and in ADL (Ref 7):

Abel Heat Test at 82.2° – 30 seconds, vs 10 mins for NG

Hygroscopicity – none

Impact Test with 10kg wt – positive at 110cm fall

Power, by Ballistic Mortar Test – 102% NG

Power, by Traulz Test – 173% TNT

Note: A Blasting Gelatin contg 93% of 2-Nitroethanol Nitrante and 7% Collodion Cotton produced a lead block expansion (Traulz Test) of 500ccc vs 600ccc for Blasting Gelatin contg 93% NG. The same two expls gelatins tested by Ballistic Mortar gave a slightly higher value for gelatin contg 2-Nitroethanol Nitrante

Thermal Stability at 120° – brown fumes after 90 mins

Vacuum Stability at 100° – 11.5ccc/40 hours

Its use in expls is not recommended on account of high volatility and unsatisfactory stability

It is described as an explosive in Ref 8 and its Potassium Salt, C₂H₅KN₂O₅, is described in Ref 9

Ref:s: 1) Beil 1, 339–40 2) F.A. Kekulé, Ber 2, 329 (1869) 3) H. Wieland & E. Sakellarios, Ber 53, 201 (1920) 4) NaOD, NG (1928), 220–21 5) Davis (1943), 228


Ethanol, 2-Nitronitrite; 2-Nitroethanol Nitrante; 1-Nitrosoxy-2-nitroethanol or β-Nitroethyl Alcohol, O₂N.CH₂.CH₂.ONO; mw 120.065, N 23.33%, OB to CO₂ – 26.6%; not found in the open literature

Ref:s: 1) Beil, not found 2) CA, not found

Ethanol-2,2-Dinitro; 2,2-Dinitroethanol, 1-Hydroxy-2,2-dinitroethanol or β-Dinitroethyl Alcohol, (O₂N)₂CH.CH₂.OH; mw 136.06, N 20.58%, OB to CO₂ –11.7%; colorless oil;

mp 2–3° (wh crystals from ethyl chloride); bp 50–60° (0.2mm Hg, cyclic molecular still); nD 1.471 at 20°; stable at –20°; sol in w, eth; corrosive to skin; prepd by acidification with sulfuric acid of the potass-sol in w, eth; corrosive to skin; prepd by acidification with sulfuric acid of the potass-salt of the aci-form prepd from formaldehyde and potassium dinitromethanate (Ref 2)


Ethanol-2,2,2-trinitrito; 2,2,2-Trinitroethanol-1-ol; 1-Hydroxy-2,2,2-trinitroethane or β-Trinitroethyl Alcohol, (O₂N)₃C.CH₂.OH; mw 181.06, N 23.21%, OB to CO₂ +13.2%; colorless hygroscopic ndls; mp 27–30° (Ref 4) or 36–37° (Ref 6) or 72° (Ref 9); bp 103° at 14mm and 77–80° at 4mm; nD 1.4578 at 20°; sl sol in cold w and very sol in hot w. It was first prepd in 1941 by C.H. Hurd & A.C. Starke of Northwestern University, but their method was not published in open literature: it consisted of interaction between nitroform and parafomaldehyde:

3CH(NO₂)₃ + (HCHO)₃ → (O₂N)₃C.CH₂OH

The same method, essentially, was used by later investigators (Refs 2 & 4) and also by Ficherouille & Gay-Lussac (Ref 6). They treated nitroform by slowly adding an excess of parafomaldehyde (which they called trioxyméthylène), keeping the mixture at below 70–80° by cooling because the reaction is very exothermic. The resulting trinitroethanol can be distd betw 80 & 95° at 5mm pressure and crystallized in colorless ndls of mp 36–37°. Yield 65%. Dsm is very hazardous and for this reason careful control of temp is very important. Purification by forming the acetate, distg it betw 85 & 95° (in vacuo), followed by saponification is recommended by F & G (Ref 6). US Rubber Co (Ref 3) prepd it from nitroform,
formaldehyde & KOH, obtg crystals (after purification) with bp 80° at 2mm pressure and detonating by a hammer blow. Schenck & Wetterholm (Ref 7) prep’d it and used it as a starting material for prep of bis(2,2,2-trinitroethylenediimine)

Its heat of combsn was detd at PicArsn as 1291 kcal/kg. Acctd to Fichouille & Gay-Lussac (Ref 6), Trinitroethanol is unstable and even at RT evolves nitrous fumes. When heated to 120° it rapidly decomposes with evolution of nitrous fumes and then violently explodes. Its sensitivity to shock is comparable to that of NG. Although it is a good gelatinizer for NC, it cannot be recommended for use in exps and proplnts on account of its poor stability. In the 100°C Heat Test, it lost 68% 1st 48 hrs and 26% 2nd 4 hrs, with no loss in 100 hrs. Refs: 1) Beil, not found 2) W. Hunter et al, BIOS Final Rep No 709, HMStationary Office, London (1946), p 9 (Description of prep of Trinitroethanol by Dr Schimelschmidt of IG Farbenindustrie, Höchst-am-Main)


Ethanol-2,2,2-trinitro-1-nitrate; 1-Nitroxy-2,2,2-trinitroethane; 2,2,2-Trinitroethylic Alcohol Nitrate, (O₂N)₂C₂H₄(ONO₂)₃; mw 226.07, N 24.78%, OB to CO₂ -28.3%. This compd was considered to be too sensitive for use as an HE (Ref 2)

Preparation of this compd is probably by nitration of trinitroethanol prepared from nitroform and formaldehyde

Refs: 1) Beil, not found 2) CA, not found 3) A.H. Blatt, OSRD Rept 2014 (1944) (2,2,2-Trinitroethyl Nitrate) 4) ADL, Pure Expl Compds, Par 1 (1947), p 120

Ethanol Acetate and Derivatives. See Ethyl Acetate and Derivatives

Med 5(10), 491-8 (1963) & CA 60, 6120f (1964) (Threshold limit value for parent)
L) H. Mueller, GetP 1159731 (1963) & CA 60, 6553h (1964) (Mentions prep of parent-HN₃)

Ethanolamine-Diphenylcarbamide Complexes.
See under Diphenylcarbamide Complexes Suitable as Stabilizers and Gelatinizers for Smokeless Propellants, in Vol 5, pp D1445-46

Ethanolaminonitrate-methylurethane,
\[
\text{OC} \quad \text{OH} \quad \text{ONOO}_2 \\
\text{NH} \quad \text{CH}_2 \quad \text{CH}_2 \\
\text{H}_2
\]

MW 164.12, N 17.07%, OB to CO₂ 68.3%, bp 115-20º (0.5 tare), sp gr 1.461, nd 1.4735 at 25º, heat of combustion 2454.9cal/g. Prep not given in open literature
Refs: 1) Beil, not found 2) P. Tavernier & M. Lamouroux, MP 37, 201 & 206(1955) & CA 51, 717a(1957)

Ethanolamino-tetrazido-copper or Aminoethanolbis[copper(II) diazide],
H₂N.CH₂.CH₂.OH.Cu₂(N₃)₂; mw 292.71, N 62.21%, OB to CO₂ 46.4%, expl 186º (impure, Ref 2). It forms an HCl salt which neither melts nor explodes (Ref 3). See the CA for Ref 2 for prep
Refs: 1) Beil - not found 2) M. Straumanis & A. Cirulis, ZAnorgChem 251, 335-54 (1943) & CA 37, 6574(1943) 3) Ibid, 252, 9-23(1943) & CA 38, 3564(1944)

Ethanolamine and Derivatives. See ANILINOETHANOL AND DERIVATIVES in Vol 1 of Encycl, pp A424 to A429. Its expl derivative 2-(2',4',6'-Trinitro-N-nitrilino)-ethanol Nitrate, described on p A425-L, is called β-(2,4,6-Trinitrophénylnitramino)-ethyl Nitrate in Blatt, OSRD 1944(1944) and code named Péntryl. Compare with Ethyltetral, which is described under N-Ethylaminoil or N-Ethylphenylamine and Derivatives

Ethanolbenzene or Phenylethanol and Derivatives
Ethanolbenzene, Hydroxyethylbenzene, β-Phenylethyl Alcohol, Phenethyl Alcohol or Benzycarbino1, C₆H₅.CH₂.CH₂.OH; mw 122.16, colorless oil, sp gr 1.023 at 13/4º, nd 1.5310, fr p -27º, bp 219-21º at 75mm; sl sol in w; miscible with alc & eth; sol in 50% alc and in glycerol; sl sol in mineral oil. It can be prepd by reduction of phenylacetic ethyl ester by Na in abs alc or by the action of ethylene oxide on phenyl MgBr and subsequent hydrolysis; used in organic synthesis, cosmetics, medicine, etc
Refs: 1) Beil 6, 478 & 448 2) CondChemDict (1961), 874-L (Phenethyl Alcohol)

Ethanol-2,4-dinitrobenzene or β-(2,4-Dinitrophenyl) ethanol,
HOC₆H₅.CH₂.C₆H₄(NO₂)₂; mw 212.16, N 13.20%. Prep of the 3,5-dinitro by diborane reduction of HO₃C.CH₂.C₆H₄-3,5(NO₂)₂ is given in Ref 3; no props mentioned. Ref 4 mentions prep by nitration of the parent, but CA does not indicate which isomer. The 2,4-dinitro is mentioned in Refs 2 & 5 without prep or props

Ethanol-2,4,6-trinitrobenzene or β-(2,4,6-Trinitrophenyl)-ethanol,
HOC₆H₅.CH₂.C₆H₄(NO₂)₃; mw 257.16, N 16.35%, OB to CO₂ -77.8%, mp 112º(Ref 6). It was prepd by refluxing TNT with amine HCHO at 90º(Ref 6); used to prepare the corresponding ethyl chloride, mp 72º(Ref 3), 78º(Ref 6); used to prepare the 2,6-dinitro-4-amino compd; yel, mp 161-65º(Ref 2)

Ethanol Nitrate-nitrobenzene or β-(Nitrophenyl)-ethanol Nitrate, O₂N.O.CH₂.CH₂.C₆H₄(NO₂)₂; mw 212.6, N 13.20%. Prepn of the ortho compd by nitration of the parent at or below 0°C (Refs 2, 3 & 7) by nitrating benzocyclobutene (Refs 5 & 6); bp given as 85–105°C (0.05 torr) and nD 1.546–550 (Ref 2), and 120–40°C (2 torr) and nD 1.5799–1.5779 (Ref 5). Prepn of the para compd by nitration of parent below 0°C (Refs 3 & 7), and nitration of benzocyclobutene (Ref 6); mp given as 56–58°C (Ref 3), 32°C (Ref 6); nD 1.5735 (Ref 6). Prepn of meta compd mentioned in Ref 3 by nitration of parent below 0°C


Ethanol-2,4-dinitrobenzene Nitrate or β-(2,4-Dinitrophenyl)ethanol Nitrate

O₂N.O.CH₂.CH₂.C₆H₄(NO₂)₂; mw 257.16, N 16.35%, OB to CO₂ -77.8%. Prepn of 2,4- and 2,6-compds by nitration of the parent (Ref 3). Ref 2 indicates an (unspec'd) isomer which is insol in water and will gelatinize NC


Ethanol-2,4,6-trinitrobenzene Nitrate or β-(2,4,6-Trinitrophenyl)ethanol Nitrate, called in Blatt: β-(2,4,6-Trinitrophenyl)-ethyl Nitrate, O₂N.O.CH₂.CH₂.C₆H₄(NO₂)₃, mw 302.16, N 18.54%, OB to CO₂ -53%; solid, mp 83°C. It was prep'd by Vender in impure state, as oil, by nitrating β-phenylethyl alcohol. Another method was by condensing TNT & formaldehyde to β-(2,4,6-Trinitrophenyl)-ethyl alcohol and nitrating this compd (Ref 2)

The oil product was examined during WWII in the labs of duPont Co and found that it cannot be detonated by the impact of an 8-oz steel ball dropped 25 inches, but was detonated by a hammer blow (Ref 3)

Refs: 1) Beil 6, (239) 2) V. Vender, Gazz 45 (II), 91 (1915) & CA 10, 1513 (1916) 3) A.H. Blatt, OSRD Rept 2014 (1944) 4) Not found in later refs thru 1972

Ethanol Chloride. See Chloroethanol in Vol 3, p C254-R

Ethanol-N-diphenylamine. See Diphenylaminooethanol in Vol 5, p D1441-R

Ethanol Diphenylurea [1,1-Diphenyl-3-(2-hydroxyethyl)-Urea; 3-(2-hydroxyethyl)-1,1-diphenylurea; and 2-(2-hydroxyethyl)-1,1-diphenylurea (CA)], (C₆H₄)₃NCONH.CH₂.CH₂.OH; mw 256.25, mp 117.5°C, heat of combustion 7349.5cal/g. It was prep'd by reacting N,N-diphenylcarbamoyl chloride with ethanolamine (Ref 3)


Ethanololstylenediemimine and Derivatives

N-Ethanol; ethylenediamine; N-(2-Hydroxyethyl)ethylenediamine; or 1-Hydroxy-3,6-diazabexane, HO.CH₂.CH₂.NH.CH₂.CH₂.NH₂; mw 104.15, bp 238–40°C, sol in w, acl; hygroscopic; prep'd from ethylene oxide and ethylene diamine (Ref 1)

1-Nitroxy-3,6-diazabexane Dimitrte, O₂N.O.CH₂.CH₂.NH.HNO₃.CH₂.CH₂.NH.HNO₃;
E 183

mw 275.18, N 15.27% (NO₃), OB to CO₂ ∼32.0%. UV spectrum (Ref 2). It was probably prepd by nitration of the parent; nothing in the open literature.


N-Ethanolglucosamol or N-(2-Hydroxyethanol)glucosamol, HOCH₂(CHOH)₂CONH.CH₂.CH₂OH; mw 239.23, mp 109° [α]D²₀ +34.15°. It was prepd by refluxing ethanamine with a gluconic lactone derived from date seed.

Refs: 1) Beil, not found 2) K.J. Goldner & C.H. Rogers, J. Am. Pharm. Assoc. 28, 364–9 (1939) & CA 33, 7278 (1939)

N-Ethanolglucosamone Hexanitrate, O₂N.O.CH₂(CHONO₂)₂CONH.CH₂.CH₂.OONO₂; mw 509.21, N 16.50% (NO₂), OB to CO₂ −7.85%. It was prepd by mixed acid nitration of the preceding entry (Ref 2); no props given.

Refs: 1) Beil, not found 2) W.F. Fillbert, USP 2443903 (1948) & CA 43, 1796f (1949)

Ethanoxyacetamide and Derivatives

N-Ethanoxyacetamide or N-(2-Hydroxyethyl)glycolamide, HOCH₂CONH.CH₂.CH₂OH; mw 119.11, mp 71−2°, bp 195−200° (1.5 torr, dec.). It was prepd by heating ethanamine with methyl hydroxyacetate.

Refs: 1) Beil, not found 2) F.M. Meigs, USP 2347494 (1944) & CA 39, 1176 (1945)
3) Q.F. Soper er al., JACS 70, 2837−43 & CA 43, 3364f (1949)

N-Ethanoxyacetamide Dinitrate, O₂N.O.CH₂.CH₂.OONO₂; mw 289.12, N 13.39% (NO₂), OB to CO₂ −34.4%; prepd by mixed acid nitration of the preceding entry (Ref 2); no props given. It was proposed for use in blasting caps & detonators (Ref 2).

Refs: 1) Beil, not found 2) W.F. Fillbert, USP 2443903 (1948) & CA 43, 1796f (1949)

Ethanolmethyleneamidine and Derivatives

N-Ethanol-N-methyleneamidine or 1-Hydroxy-3,6-diazeabutane, HO.CH₂.CH₂-NH.CH₂.CH₂-NH.CH₃; mw 118.18. It can be made from N-methyllethyleneamidine by adding ethylene oxide (Ref 3).

N-Ethanolnitrilate-N-methyl-ethylenedinitramine, called in Canad paper: 1-Nitroxy-3,6-dinitro-3,6-diazeabutane, (O₂N)₂.CH₂.CH₂.N(NO₂)₂.CH₂.CH₂.N(NO₂)₂.CH₂, mw 253.17, N 16.60% (NO₂), OB to CO₂ −53.7%, mp 90.5−92° (Ref 3); prepd indirectly from the parent by nitratio followed by cleavage of a coupling compd (Ref 3).


Ethanolnitramine. See 1-Nitraminoethanol in Vol 1 of Encycl, p A200-R, under Aminoethanol

Ethanol Nitrilo and Derivatives

Ethanol Nitrilo or Triethanolamine, N(CH₂.CH₂.OH)₃; mw 149.19, bp 206−207° (15 torr), 277−79° (150 torr), sp gr 1.1242, nD³ 1.4852, sol in CHCl₃, hygroscopic. It was prepd by action of ammonia on 2-chloroethanol, or on ethylene oxide.

Nitrilotriethoxamethane or Tris(2-nitroxyethyl)amine, N(CH₂.CH₂.OH)₂; mw 284.18, N 14.79% (NO₂), OB to CO₂ −50.7%. It was prepd by nitratio of the alcohol, neutralization with NaHCO₃, extraction in ether (Ref 5). Thin layer chromatograph Rf values given in Ref 7.

Nitrilotriethoxamethane nitrate or Tris(2-nitroxyethyl)amine nitrate, HNO₃.N(CH₂.CH₂.OH)₂; mw 347.20, N 16.14% (NO₂), OB to CO₂ −30.0%, mp 74−75° dec (polymorph mp 64−5°, Ref 4), extremely unstable, dec violently; prepd by nitratoing the alcohol in Ag₂O at −5 to −10°.

Ethanol-2-oxyp propane-2,3-diol Trinitrate,\( \text{CH}_2\cdot\text{CH}_2\cdot\text{ONO}_3 \)\( \text{CH}_2\cdot\text{CH}(\text{ONO}_2)\cdot\text{CH}_3(\text{ONO}_2)\); mw 271.14, N 15.50%, OB to CO\(_2\) 26.5%, sp gr 1.481, n\(^D\) 1.4685, heat of combustion 2405.1cal/g. It was prepd by nitration of parent with mixed acid at room temp (Ref 4).


Ethanol Perchlorate, HO.CH\(_2\cdot\text{CH}_2\cdot\text{OCIO}_4\); mw 144.51, OB to CO\(_2\) 16.6%, sp gr more than 1.7, sol in Et\(_2\)O; sol in w, dec violently on heating, impact, grinding; prepd by adding ethylene glycol to perchloric acid at -75 to -78\(^\circ\)C (Ref 3). Power by Trauzl Test 110% PA or 120% TNT. It is extremely sensitive.


Ethanol 2-2',2''-nitritro-nitrate, Dimer or 1,1,4,4-Tetrakis(2-hydroxyethyl)piperazinium Dinitrate, Tetranitrate, C\(_{15}\)H\(_{24}\)N\(_8\)O\(_{18}\); mw 568.37, N 14.79% (NO\(_2\)), OB to CO\(_2\) 50.7%, mp 216\(^\circ\)C (dec). It was prepd from nitritro-nitrate and base at 0°C.

Ref s: 1) Beil - not found 2) G.E. Dunn, R.H. Meen & G.F. Wright, JACS 74, 1344-45 (1952) & CA 47, 12394i (1953)

Ethanol, Nitroxytrinitro. See Ethanol-2,2,2-trinitro-1-nitrato under Ethanol Derivatives

Ethanol-2-oxyp propane-2,3-diol, HO.CH\(_2\cdot\text{CH}_2\cdot\text{OC}_2\cdot\text{CH}(\text{OH})\cdot\text{CH}_2\cdot\text{OH};\) mw 136.15, bp 145-50\(^\circ\) (1torr), 162-4\(^\circ\) (3torr), n\(^D\) 1.4723, sp gr 1.218, heat of combustion 4946.5cal/g. It was prepd by reacting ethylene glycol with epichlorohydrin and hydrolyzing the intermediate (Ref 2)

Ethanol-2-oxyp propane-2,3-diol Dinitrate, HO.CH\(_2\cdot\text{CH}_2\cdot\text{O.C}_2\cdot\text{CH}-(\text{ONO}_2)\cdot\text{CH}_2\cdot\text{ONO}_2;\) mw 226.14, N 12.39%, OB to CO\(_2\) 49.6%. It was probably prepd by partial nitration of the parent; no mention in the open literature.

Ref s: 1) Beil - not found 2) M.S. Kharasch & W. Nadenberg, JOC 8, 189-93 (1943) & CA 37, 3736 (1943) 3) L. Méard & M. Thomas, MP 37, 129 (1955) & CA 51, 716h (1957)

Ethanethiol. See Ethyl mercaptan

Ethene. See Ethylene

Ethanoxethene. See Divinyl Ether or Divinyl oxide in Vol 5 of Encycl, p D1526-L

Ethenylamine or Ethanamidine. See \(\alpha\)-Amino-\(\alpha\)-imidoethane in Vol 1 of Encycl, p A223-L

Ethenylamidoxime and Derivatives
Ethenylamidoxime or Acetamidoxime, CH\(_3\)C(=NOH)NH\(_2\); mw 74.08, N 18.77% (NO),
mp 135°(dec), sol in w and alc, dec in warm w.
Prepd by addn of H₂NOH to CH₃CN
Refs: 1) Beil 2, 188 2) J. Barrans, R.
Mathis-Noel & F. Mathis, CR 245, 419-22
**Nitroethenylamidooxime**, O₂N-CH₂-C(=NOH)N₃H₃; mw 119.08, N 23.52%
(NO), OB to CO₂ -47.0%, yel cryst, dec 108°,
sol in hot alc; prepd from the ammonium
salt of nitroacetoniitrile and hydroxylamine
hydrochloride (Ref 2)
Refs: 1) Beil 2, 227 & (100) 2) W. Steinkopf
& L. Bohmann, Ber 41, 1050(1908)

Some unstable derivs of Ethenylamidoöxime include:

**N-Hydroxyethenylamidooxime**,
CH₃C(=NOH)NH₂OH; mw 90.08, N 31.10%, oil,
dec explosively when dry. Prepd by sodium
amalgam reduction of ethyl nitrosamine (Ref 1)
Refs: 1) Beil 2, 189 2) J. Armand, CR 258(1),
207-10(1964) & CA 60, 10498(1964) 3) Ibid,
262(7), 592-5(1966) & CA 64, 19406(1966)
(Prep of the HCl salt) 4) F. Valentin.,
P. Gouzär & P. Souchay, JChimPhysPhysico-
ChimBiol 1971, 68(4), 601-4 & CA 75, 54125m
(1971)

**N-Oxoothenylamidooxime** (Äthylnitrosolsaüre in
Ger), CH₃C(=NOH)NO; mw 88.06, N 31.81%,
OB to CO₂ -72.7%, unstable in free state; prepd
from following entry by reduction with sodium
amalgam
Refs: 1) Beil 2, 189 2) H. Wieland, Ann 353,
90(1907) 3) J. Armand, CR 258(1), 207-10
(1964) & CA 60, 10498(1964)(Prepn) 4) F.
Valentin., P. Gouzär & P. Souchay, JChim-
PhysPhysicochimBiol 1971, 68(4), 601-4 &
CA 75, 54125m (1971)

**N-Dixothenylamidooxime** (Äthylnitroksäure in
Ger), CH₃C(=NOH)NO₂; mw 104.065, N 26.92%,
OB to CO₂ -46.1%, rh cryst, mp 81-2°(dec),
87-8°, very sol. It was prepd from nitric acid
and sodium salt of nitroethane (Ref 2)
Refs: 1) Beil 2, 189 2) V. Meyer, Ann 175,
98(1875) 3) A.I. Ivanov et al, ZhOrgKhim 2
(5), 763-6(1966) & CA 65, 12098(1966)(UV,
IR spectra)

O-1-(1,1-dinitroethane)ethenylamidooxime,
CH₃C[=NO₂C(=NO₂)₂CH₃]N₂H₂; mw 192.13, N
21.87%(NO), OB to CO₂ -58.3%, mp 95-97°
dec, wh ndls, not stable prepn is in Ref 2
Refs: 1) Beil - not found 2) J.S. Belew,
C.E. Grabel & L.B. Clapp, JACS 77, 1110-14
(1955) & CA 50, 1648(1956)(Prepn) 3) A.I.
Ivanov et al, ZhOrgKhim 2(5), 763-7(1966) &
CA 65, 12098(1966)(UV, IR spectra)

**N-Dioxo-0-1-(1,1-dinitroethane)ethenylamido-
oxime or 2,5,5-Trinitro-3-oxo-4-oxa-2-hexene**, 
CH₃C[=O-C(NO₂)₂CH₃]N₂O₂; mw 222.115, 
N 25.22%, OB to CO₂ -28.8%, mp 121.2-121.6°,
wh plts. It was prepd by reacting NH₄ or K
salt of 1-nitroethenitrone with 1,1-dinitro-
ethane (use at most 5g of salt) (Ref 1); inert
to hot nitric acid; does not form a perchlorate
salt
Refs: 1) J.S. Belew, C.E. Grabel & L.B.
Clapp, JACS 77, 1110-14(1955) & CA 50,
1648(1956)(IR spectrum) 2) A.I. Ivanov et
al, ZhOrgKhim 2(5), 763-6(1966) & CA 65,
12098(1966)(UV & IR spectra)

**Ethenyl diphenylamidine.** See NN'-Diphenyl-
acetamidine in Vol 5 of Encycl, p D1414-R

**Ether, Diethyl; Ethyl Ether or Sulfuric Ether.**
See Diethyl Ether in Vol 5 of Encycl, pp D1233
to D1235, where its preparation, properties and
some qualitative tests are described. Its
requirements and tests, as outlined in US Specifi-
cation MIL-E-199A (1), are not described there,
but are described below

Uses of Ether. One of the important applications
of ether is in manuf of single-base prop-
pellants where it is used in 2:1 mixture (by wt)
with ethanol. The procedure is described in
Vol 3 of Encycl, p C399, under Colloiding
Agents and Colloidal Propellants

Another important use of ether is in analyses
for extraction of materials soluble in it. For
example, in extraction of nitrocompounds, known
as "Nitrobodies" (NB), always present in spent
acids of TNT manuf, the following procedure is
described in Clift & Fedoroff's Manual for
Explosives Laboratories, Lefax, Inc., Phila, Pa,
Vol I(1943), Chap 1, Pt 3, p 21-2: Shake the
crushed spent acid and pour 50.00g
into a tared porcelain or Pyrex dish of about
100ml capacity, using a pulp balance. If the
acid solidified due to an excessive amt of NB's,
warm the bottle in water prior to pouring. Transfer the sample from the dish into a 400ml beaker containing 200ml ice-water mixture and then into a 500ml separatory funnel. Add 50ml of ether and remove the funnel from the support, while holding the stopcock firmly with the right hand. Close the top of the funnel with a ground glass stopper and, while pressing against it with the palm of the left hand, carefully invert the funnel. Immediately after this, open the stopcock to allow the vapors of ether to escape. Close the stopcock and, while holding the funnel in an inverted position, shake the mixture gently and then open the stopcock, being careful that none of the liquid escapes. Repeat the shaking operation 2 or 3 more times and then replace the funnel on the support. After allowing the funnel to stand until the two layers separate, open the stopcock and draw off the bottom layer (acid-water) into the same 400ml beaker as above. Allow a few drops of the ether to enter the beaker to avoid leaving any acid in the ether layer and then close the stopcock. Place the tared dish used for weighing the 50g sample of acid, underneath the stopcock of funnel and draw off the ether layer into the dish. Place the dish on a water bath and, while the ether evaporates, pour the acid-water from 400ml beaker into the same separatory funnel. Add 50ml of ether and extract NB’s in the same manner as above and transfer the ether extract into the above dish after nearly all the ether of the 1st extraction has been evaporated. Repeat the extraction and separation using 25ml of ether, etc. The extracted material in the dish should be heated until complete disappearance of ether odor, then cool the dish in a desiccator and weigh.

\[
\% \text{NB} = \frac{\text{Wt of residue in the dish}}{\text{Wt of sample}} \times 100
\]

Note: As small amounts of acid may be retained in the ether extracts, it might be advisable (for more precise analysis) to collect the three ether extracts in a 250ml separatory funnel, wash with about 50ml water, and then proceed with the evap of ether.

**Ether, Diethyl.** US Armed Forces Specification Requirements and Tests for material used in manuf of smokeless propellants and for cleaning optical instruments is covered by MIL-E-199A (1) with AMD 2(MU), 3 June 1968. Their contents are as follows:

1. **SCOPE**
2. **APPLICABLE DOCUMENTS**
   2.1. A list of documents which includes Federal and Military Specifications, Ordnance Corps Publications, etc is given in the above Spec
   2.2. Other publications, which include the "Interstate Commerce Commission Rules and Regulations for the Transportation of Explosives and Other Dangerous Articles", and ASTM (American Society for Testing and Materials) D1209-69 publication, entitled "Standard Method of Test for Color of Clear Liquids" (Platinum-Cobalt Scale) are listed in the same Spec

3. **REQUIREMENTS**

3.1. **Material.** Diethyl ether shall be made from ethyl alcohol conforming to the requirements for grade 1 or grade 2 of Specification MIL-A-463 (See in this Vol under Ethanol), or ether shall be made as a co-product in the manuf of Ethanol from ethylene

3.2. **Appearance.** Ether shall be no darker than the 20 Platinum-Cobalt Standard when tested as specified in paragraph 4.3.1

3.3. **Chemical and Physical Properties.** The diethyl ether shall conform to the requirements specified in Table 4.3.

### Table 4.3 Chemical and Physical Requirements

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification at 20/20°C</th>
<th>0.712 to 0.723</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonvolatile residue, % by weight, maximum</td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>Acidity, as acetic acid, %, max</td>
<td></td>
<td>0.006</td>
</tr>
<tr>
<td>Acetylene, %, max</td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Peroxides</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Chlorides</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Aldehydes</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

(Not applicable when ether is intended for use in manuf of smokeless propellants)

4. **QUALITY ASSURANCE PROVISIONS** are described on pp 2-7

This includes among other items the description of sampling from 55-gallon metal containers or from tank cars in which ether is delivered to Ordnance Installations

4.2.3.1.1. **Containers** (p 5). Select from each inspection lot two containers at random and
remove from each about 16 oz, to a bottle provided with a glass stopper, thus making a 32-oz composite sample. Label the bottle

**Note:** A lot shall consist of one or more batches of ether, produced by one manufacturer, under one continuous set of operating conditions and submitted for acceptance at one time. Each batch shall consist of that quantity of ether that has been subjected to the same unit chemical or physical mixing process intended to make the final product homogeneous

4.2.3.1.2. **Tank Cars.** Attach a clean, tared, small-necked glass bottle of about one quart size to a rod equal in length to the diam of tank car. Lower the unstoppered bottle quickly inside the tank to its bottom and start immediately to withdraw it to the surface. In order to obtain a representative cross-section of the material, the speed of lowering and raising the bottle shall be uniform and so regulated that the bottle is just filled as it reaches the surface of ether in the tank. Transfer the sample to a glass bottle provided with a glass stopper and attach a label

4.3. **Test Method and Procedure**

4.3.1. **Appearance.** It shall be determined in accordance with ASTM Designation D1209–69, entitled "Standard Method of Test for Color of Clear Liquids" (Platinum-Cobalt Scale)

**Apparatus:**

a) Beckman Model B Spectrophotometer or any other instrument having equivalent resolution and sensitivity

b) Spectrophotometer Cells, matched, having a 10-mm light path

c) Color Comparison Tubes. Matched 100-ml tall-form Nessler tubes, provided with ground-on optically clear glass caps. The height of the 100-ml mark should be 275 to 295 mm above the bottom of the tube
d) Color Comparator. It shall be constructed to permit visual comparison of light transmitted thru the above Nessler tubes in the direction of their longitudinal axes. The white light shall pass thru or be reflected off a white glass plate and directed with equal intensity thru the tubes and shall be shielded so that no light enters the tubes from the side

**Reagents:**

a) Water must be "reagent grade" conforming to ASTM Spec D193

b) Cobalt Chloride, CoCl₂.6H₂O, Hydrochloric Acid (sp gr 1.19) and Potassium Chloroplaintate, K₂PtCl₆, shall conform to ASTM Method E200 c) Platinum-Cobalt Stock Solution. Dissolve in 1-liter volumetric flask 1.245 g of K₂PtCl₆ and 1.000 g of CoCl₂.6H₂O in about 800 ml of reagent-grade water, add 100 ml HCl and dilute to 1 liter with water. The absorbance of this "stock solution" is supposed to be 500 but it should fall within the limits given in Table 4 for various wavelengths. The measurements shall be made in a cell having a 10-mm light path using a Beckman Model B Spectrophotometer at a sensitivity setting of one, or in an equivalent spectrophotometer. Reagent water in a matched cell shall be used as the reference soln

**Table 4**

<table>
<thead>
<tr>
<th>Wavelength, nm</th>
<th>Absorbance</th>
</tr>
</thead>
<tbody>
<tr>
<td>430</td>
<td>0.110 to 0.120</td>
</tr>
<tr>
<td>455</td>
<td>0.130 to 0.145</td>
</tr>
<tr>
<td>480</td>
<td>0.105 to 0.120</td>
</tr>
<tr>
<td>510</td>
<td>0.055 to 0.065</td>
</tr>
</tbody>
</table>

**Platinum-Cobalt Standards.** By diluting 1, 2, 3, 4, 5 and 6 ml, each to 100 ml with reagent water, Color Standards Nos 5, 10, 15, 20, 25 and 30, respectively, are obtd. Table 2 of D1209-69 Standards lists several more concentrated standards up to Std No 500, but for Ether of US Spec they are not required, since its color shall not be darker than No 20 Standard Procedure:

Introduce 100 ml of ether under test into a Nessler tube, passing the sample thru a filter if it has any visible turbidity. Cap the tube with a transparent cover and place it in the "comparator", while side-by-side with it is placed one of the standards. Report as the color the number of the standard that most nearly matches the sample. In the event that the color lies midway between two standards, report the darker of the two. If, owing to differences in hue betw the sample and the standards, a definite match cannot be obtd, report the range over which an apparent match is obtd, making a note that it is "off-hue"

4.3.2. **Specific Gravity**

4.3.2.1. **Pycnometer Method.** Sp gr shall be determined in accordance with Federal Test Method No 141 Method 4183, except that the temperature shall be 20/20°C

**Note:** Pycnometer Method is also described
in Vol 3 of Encycl, pp D69 to D71

4.3.2.2. Westphal Balance Method (Alternative Method). Sp gr shall be detd in accordance with Federal Test Method No 141 Method 4183, except that the temp shall be 20/20°C

Note: Westphal Balance Method is described under Hydrostatic Weighing Method in Vol 3 of Encycl, p D68

4.3.3. Nonvolatile Residue. Transfer 100ml of the sample to a tared dish and after evaporating to dryness on a steam bath, place the dish for one hour in an oven at 100°C. Cool in a desiccator, weigh and calculate

\[ \text{% Nonvolatiles} = \frac{100A}{BC} \]

where:

- \( A \) = wt of residue in grams
- \( B \) = volume of sample and
- \( C \) = sp gr of sample

4.3.4. Acidity. Prepare the bromothymol-blue indicator soln by dissolving in a 100ml volumetric flask 100mg of bromothymol blue in 20ml of acid-free alcohol and adding distilled water to make 100ml of soln. Introduce into a colorless flask provided with a tightly-fitting glass stopper, 2 drops of the above indicator soln and add dropwise from a 25ml burette 0.001N NaOH soln to the first blue color that remains permanently developed. Add 50ml of the sample, shake well to mix the two layers and titrate with 0.001N NaOH soln to the first blue color that persists for several mins. Close the bottle (to prevent introducing any carbon dioxide from the atm); wait until two layers separate and then judge the color. Small parts of alcohol in the soln dim the color, while large parts give an indefinite end point. Opalescence occurs when ether is slightly alkaline. Calculate acidity as % of Acetic Acid

\[ \% \text{Acetic Acid} = \frac{6.0VN}{AB} \]

where:

- \( V \) = ml of NaOH soln used in titration
- \( N \) = normality of NaOH soln
- \( A \) = ml of sample used
- \( B \) = sp gr of sample

4.3.5. Peroxides. Transfer 10ml of the sample to a 10ml colorless cylinder, provided with a glass stopper, add 1ml of soln prepbd by dissolving 0.5g KI and 0.5g CdCl₂ in 9ml of distilled water. Stopper the cylinder and keep it in a dark place for 1 hour, while shaking occasionally. If ether layer darkens, peroxides are present

4.3.6. Chlorides. Transfer 10ml of the sample to a test tube and add 4 to 5ml of a 10% silver nitrate soln. If an opalescence appears, introduce one drop of nitric acid by means of a stirring rod. Persistence of opalescence indicates the presence of chlorides

4.3.7. Aldehydes. Prep the reagent by mixing 1ml of alkaline mercuric potassium iodide with 17ml of a satd aq soln of NaCl. Transfer 10ml of the sample to a colorless cylinder, provided with a glass stopper and add 1ml of the above reagent. Stopper the cylinder, shake vigorously for 10 secs and then set it aside for 1 min. Persistence of turbidity in the aqueous layer indicates the presence of aldehydes

Note: This test is not required for ether intended for use in the manuf of smokeless propllnts

4.3.8. Acetylene. Add 10 drops of freshly prepbd 0.1% methyl red indicator soln to each of two 250ml Erlen flasks contg 50ml of 50% ethanol soln. Reserve one of the flasks as a blank and add 10ml of the sample to the other. Neutralize the acidity in each of the flasks and match their colors exactly by adding to each flask 0.02N alcoholic silver nitrate soln and then titrate the sample and blank with standard 0.02N NaOH soln to the same yellow end point. Calculate as follows:

\[ \% \text{Acetylene} = \frac{1.30(V-v)N}{SD} \]

where:

- \( V \) = ml std NaOH soln required for the sample
- \( v \) = ml std NaOH soln required for the blank
- \( N \) = normality of NaOH soln
- \( S \) = ml of sample
- \( D \) = sp gr of sample

Determination of Ether in Mixtures with Ethanol, Acetone and Water

Following are the titles of procedures described or listed under ETHANOL

1) Ethanol, Ether, Acetone and Water Determinations in Solvents Used in Manufacture of Smokeless Propellants, as Described in the Literature

2) Ethanol, Ether, Acetone and Water Determinations in Nitrocelluloses and Smokeless Propellants as Described in the Literature

3) Ethanol + Ether as "Residual Solvent" Determination in Single-Base Propellants

4) Ethanol, Ether and Water Determination in Single-Base Propellants by US Army Munitions Command Method T103.5, entitled "Total Volatiles, Gas Chromatographic Method"
Following are additional references on analytical procedures involving ether:

A) Anon, IEC, New Edn, 14, 305 (1936) ( Peroxide formation in ethers and a test for peroxides in ether) (Procedure: a) Add 10 ml ether (sample to test) to 150 ml of 2N sulfuric acid soln, followed by 3 drops of 1% soln of Ammoniumpyridate (a catalyst to favor the liberation of iodine) and 15 ml of 10% KI soln. Shake well and allow to stand for 15 mins b) Titrate the liberated iodine with 0.05N Na thiosulfate and shake well after each addn until near decoloration of soln c) Add a few cc of starch soln and continue titration until disappearance of blue color

B) A. Boule, R, Mémserv Chim Etat, 36, F2, p 258 (1951) (Determination of ether by oxidation with K dichromate. Determination of the carbon dioxide formed by combustion of such hydrocarbons as ether & acetone was shown to be a suitable method for estimating 0.5-10 mg quantities in the atm.

C) H. Liogier, MP 38, 167-72 (1956) & CA 51, 11719 (1957) (Determination of ether in waste alcohols. A 5-8 g sample is suspended in 200 ml HOCH₂·CH₂OH contg 1% Ph₂NH. Under a vacuum of 40-50 cm of water created by a Marriot bottle, the mixt is heated at 95 °C with stirring until the sample dissolves or degelatinizes. While heating 850 ml of water is added slowly to ppt nitro compounds. About 250 ml of water is distilled into an intermediate flask under cooling. This flask is warmed almost to boiling and 1½ liters of air passed thru over 1½ hrs, entraining the ether which is passed thru a reflux condenser and collected in 30 ml 1.6N H₂CO₃ contg in a bubble tube in series with the Marriot bottle. The stillpot residue is distd and the alc collected in another bubbler contg H₂CrO₄ soln. The bubbler contents are titrated with thiosulfate soln and ether & alc calculated)


Éther à 56°. Fr designation of ether-ethanol mixture of 56 degrees Baumé. It consists of ether & ethanol 36% (by weight), which makes about 2 parts of ether and 1 part of ethanol, by volume. Such a mixt has been used for gelatinization of NC of ca 12.6% N during manuf of single-base proplnts not only in France, but also in the USA and other countries

Éther amylozoïtique or Éther amylnitrite. Fr for Amyl Nitrate described in Vol 1, p A397-L

Éther éthylacétique. Fr for Ethyl Acetate, described in this Vol

Éther éthylazoïtique or Éther éthylinitrite. Fr for Ethyl Nitrate

Éther éthylique. Fr for Ethyl Ether, described in Vol 4 as Diethyl Ether, p D1233

Éther méthylaizoïtique or Éther méthylinitrite. Fr for Methyl Nitrate

Ether-oxyline Explosives, patented in England in 1852 & 1853 by Winiwarter, were based on "ether-oxyline" which was a soln of Pyroxylin in 2 parts by wt of ether. It was presumably used as a binder. Daniel (Ref 1) lists the following compositions mixed with "ether-oxyline":

No 1: MF, K chloride, Sb sulfide, charcoal, saltpeter, K ferrocyanide & Mn dioxide
No 2: Zn fulminate, K chloride, Sb sulfide, Pb dioxide and K ferrocyanide
No 3: Phosphorus (amorphous), Pb dioxide, charcoal & saltpeter

Exact comps were given in Ref 2
Refs: 1) J.P. Cundill, MP 6, 118 (1893) (Gives details of comps) 2) Daniel, Dict (1902), 810 (Under Winiwarter)

Ethoxycetamide (Ethoxycetamide or Äthylätherglykolsäureamid, in Ger), C₂H₅O. CH₂CONH₂; mw 103.12, N 13.58%; plates (from benz); mp 82.5° (sublimes), bp 225° at 75 mm Hg; easily sol in w, alc, eth, benz and CS₂. It can be prepd by action of aqueous ammonia on ethyl ester of ethoxyacetic acid or by action of ammonia on acetoxycetyl chloride in ether
Ethoxycetoxide or Ethoxyacetic Acid Azide, C\textsubscript{2}H\textsubscript{5}O.C.H\textsubscript{2}.CO(N\textsubscript{3}); mw 129.12, N 32.54\%, yel pungent oil, causing tears; sol in alc, eth, benz; expl on heating; prep from ethoxyacetic acid hydrazide and HNO\textsubscript{3}.

Refs: 1) Beil 3, (94) 2) T. Curtius, JPraktChem 21, 95, 174 (1917) & CA 12, 899 (1918)

Ethoxycetanilide. See Acetamidophenolote in Vol 1 of Encycl, p A20

Ethoxacyetylene or Ethyl ethynyl ether, C\textsubscript{2}H\textsubscript{5}O.C.CH; mw 70.09, bp 50–52\(^o\)C, n\textsubscript{D} 1.3796, sp gr 0.799, dipole moment 1.94D, irritating to eyes. It hydrates explosively with concd HCl, controllably with dil HCl; unstable at room temp; reacts with CCl\textsubscript{4} slowly.

Its sodium derivative, presumably C\textsubscript{2}H\textsubscript{5}O.C.Na, explodes when exposed to air. It can be prep'd from sodamide in liquid ammonia and diethylchloracetal.

Refs: 1) Beil – not found 2) T.L. Jacobs, R. Cramer & J.E. Hanson, JACS 64, 223–6 (1942) & CA 36, 1899 (1942)(Heated bromo-ethoxyethylyene with KOH at 90–100\(^o\)C; bp 28\(^o\) at 30mm, n\textsubscript{D} 1.3812, sp gr 0.793)
3) A.E. Favorskii & M.N. Shchukina, JGenChem 15, 394–400 (1945) & CA 40, 4657 (1946)(Mentions Ag salt, wh amor, explosive)
4) D.A. van Dorp, J.F. Arens & O. Stephenson, RecTravChim 70, 289–96 (1951) & CA 45, 7950 (1951)(Heated Et\textsubscript{2}chlorovinyl ether with KOH at 120\(^o\), bp 50–52\(^o\) 5) J. Queck, AbhandBraunschweigWissGes 4, 37–47 (1952) & CA 48, 1238 (1954)(Review on prepn, reacns)
7) E.R.H. Jones et al, OrgSyn 34, 46–9 (1954), JChemSoc 1954, 1860–5 & CA 49, 5265, 8142 (1955)(Prepn from ClCH\textsubscript{2}CH(OEt)\textsubscript{2} and sodamide; mentions expl. nature of the Na intermediate in contact with air) 8) Y.A. Simmema & J.F. Arens, RecTravChim 74, 901–4 (1955) & CA 50, 4925 (1956)(Prepn of CH\textsubscript{2}O(N\textsubscript{3})\textsubscript{2}OEt from EtOCC\textsubscript{2}CH and H\textsubscript{2}O; mw 156.15, N 53.82\%, bp 46–46.5\(^o\) (10 torr), n\textsubscript{D} 1.4464) 9) J. Cley & J.F. Arens, RecTravChim 78, 929–34 (1959) & CA 54, 18349 (1960)(Prepn of an unstable, expl material with propionic acid) 10) L. Weinberger, ChemProd 26 (11), 23–7 (1963) & CA 60, 3994 (1964)(Review, mentions explosivity of dry Na and Li salts in air)

Ethoxyaminobenzenes. See Aminophenolote in Vol 1 of Encycl, p A240

2-Ethoxy-2-nitramino-1-nitroimidazolidine, C\textsubscript{4}H\textsubscript{11}N\textsubscript{3}O\textsubscript{5}; mw 221.17, N 12.66\% (N\textsubscript{2}O\textsubscript{5}), O\textsubscript{2} to CO\textsubscript{2} –76.0\%, mp 133.6–134\(^o\); prepn by refluxing 1-nitro-2-nitraminomimidazolidine in EtOH (Ref 2)

Refs: 1) Beil – not found 2) A.F. McKay & G.F. Wright, JACS 70, 3990–4 (1948) & CA 43, 2203 (1949)

Ethoxyanilines. See Aminophenolote in Vol 1 of Encycl, p A240

Ethoxybenzoxide or p-Ethoxybenzoyl Azide, C\textsubscript{6}H\textsubscript{5}O.C\textsubscript{6}H\textsubscript{4}.CO(N\textsubscript{3}); mw 191.19, N 21.98\%, solid, mp 31\(^o\) and explodes at higher temp. It was prep'd by Curtius & Ulmer (Refs 1 & 2) by boiling the Et ester with hydrazine, then treatment with HNO\textsubscript{2}


Ethoxydiphenylamine and Derivatives

Ethoxydiphenylamine (ortho), C\textsubscript{6}H\textsubscript{5}N.H.C\textsubscript{6}H\textsubscript{4}(OC\textsubscript{2}H\textsubscript{5}); mw 213.28, bp 135–6\(^o\) (52–1 torr) and 142–6\(^o\) (3.5 torr), sp gr 1.095, n\textsubscript{D} 1.6202. It is prep'd by heating aniline, retsarcol and calcium chloride (Refs 2 & 3)
and by reducing the vinyl ether resulting from adding acetylene to the phenol (Ref 4)


Ethoxydiphenylamine (meta), mp 59-60°, bp 154-61° (2 tort) & 170.5-172.5° (2.5 tort). See ortho for prep

Refs: 1) Beil 13, 411 2-4) See under ortho

Ethoxydiphenylamine (para), ndls, mp 71-2° and 73-4°, bp 348° and 145° (0.9 tort), sol in eth benz: prep'd by refluxing p-hydroxydiphenylamine with C₂H₅l and NaOC₂H₅ (Ref 2)


Ethoxydiphenylamine (ortho), o,p-Dinitro, C₆H₅.NH.C₆H₄(NO₂)₂.OC₂H₅; mw 303.28, yel ndls, mp 155°; prep'd from aniline and 2,3,5-trinitrophenol

Refs: 1) Beil 13, 393 2) J.J. Blanksma, RecTravChim 24, 41 (1905)

Ethoxydiphenylamine (ortho), o',p'-Dinitro, (O₂N)₂C₆H₄.NH.C₆H₄.OC₂H₅; mw 303.28, red ndls (from alc), mp 164° and 172-3°; prep'd by refluxing C₆H₅l with the Na derivative of the corresponding phenol (Ref 2)

Refs: 1) Beil 13, 366 2) M. Schöpf, Ber 22, 902 (1889) 3) H.J.v.Opstall, RecTravChim 52, 901-11 (1933) & CA 28, 26 (1934)

Ethoxydiphenylamine (meta), o,o-Dinitro, C₆H₄.NH.C₆H₄(NO₂)₂.OC₂H₅; mw 303.28, yel cryst, mp 125°. It is prep'd from aniline and 2,3,4-trinitrophenol

Refs: 1) Beil 13, 423 2) J.J. Blanksma, RecTravChim 27, 54 (1908)

Ethoxydiphenylamine (meta), o,p-Dinitro, formula same as above, mw 303.28, yel cryst, mp 170°. It was prep'd from aniline and 5-chloro-2,4-dinitro-phenetole

Refs: 1) Beil 13, 424 2) J.J. Blanksma, RecTravChim 23, 123 (1904)

Ethoxydiphenylamine (meta), o',p'-Dinitro, (O₂N)₂C₆H₄.NH.C₆H₄.OC₂H₅; mw 303.28, or-yel cryst, mp 151°, sol in alc, benz, hot alc. Prep'n not given in Ref 2

Refs: 1) Beil 13, (131) 2) Reverdin & Lokietek, Bul 17, 408 (from Beil)

Ethoxydiphenylamine (para), o',p'-Dinitro, formula same as above, mw 303.28, red plscts (from alc), mp 119-20°. It was prep'd from 2,4-dinitro-chlorobenzene and p-phenetidine

Refs: 1) Beil 13, (232) 2) A. v.Bloem, Helv 4, 1037 (1921) & CA 16, 901 (1922)

Ethoxydiphenylamine (ortho), o',o',p-Trinitro, (O₂N)₂C₆H₄.NH.C₆H₄.OC₂H₅; mw 349.085, N 12.04% (NO₂), red ndls, mp 124-5° and 136-7° (perh configational isomerism due to restricted rotation around the -NH-). It was prep'd from o-phenetidine and picryl chloride (Ref 2) or picryl azide (Ref 3)


Ethoxydiphenylamine (meta), o,o,p-Trinitro, C₆H₅.NH.C₆H₄(NO₂)₂.OC₂H₅; mw 349.085, N 12.04% (NO₂), mp 174°. It was prep'd from aniline and 3-chloro-2,4,6-trinitro-phenetol

Refs: 1) Beil 13, 425 2) J.J. Blanksma, RecTravChim 21, 326 (1902)

Ethoxydiphenylamine (para), o',o',p-Trinitro, (O₂N)₂C₆H₂.NH.C₆H₄.OC₂H₅; mw 349.085, N 12.04% (NO₂), red ndls, mp 123-4°, 136-7°, 138.5°, sol in alc & benz. It was prep'd from p-phenetidine and picryl chloride (Refs 2 & 3) or Picryl Azide (Ref 4)

Refs: 1) Beil 13, 446 2) See (2) under ortho-trinitro above 3) N.M. Cullinane, O.E. Embrey & D.R. Davies, JChemSoc 1832, 2363-4 & CA 26, 5926 (1932) 4) See (3) under ortho-trinitro above
Ethoxyethanol and Derivatives

2-Ethoxyethanol, C₆H₅O.CH₂.CH₂.OH; mw 90.12, bp 134° (721.5 torr) and 134.7–139° (748.3 torr), sp gr 1.035, nD20 1.4080. It was prep by warming C₂H₅I with Na in glycol; mentioned as solvent for cellulose nitrate in Ref 1, [518]
Refs: 1) Beil 1, 467, (244) & [518] 2) E. Demole, Ber 9, 745 (1876) 3) M.H. Palomaa, Ber 42, 3876 (1909)

2-Ethoxyethanol Azide or 2-Azidoethyl Ethyl Ether, C₂H₅O.CH₂.CH₂.N₃; mw 115.14, N 36.41%, colorless liq, bp 49° (25 torr), sp gr 0.974. It was prep by action of Ag₂O on C₂H₅I and N₃.CH₂.CH₂.OH (Ref 2). It is an expl compd

2-Ethoxyethanol Nitrate or 2-Nitrotoethyl Ethyl Ether, C₂H₅O.CH₂.CH₂ONO₂; mw 220 135.12, N 10.37%, bp 64° (12 torr), sp gr 1.111, nD20 1.4132. It was prep by nitration of the parent with HNO₃/Ac₂O (Ref 2)

1-Ethoxyethyl Hydroperoxide,
C₂H₅O.CH(OH).CH₂; mw 106.12, bp 0° (2 torr), 62–64° (14 torr), nD20 1.4091, sp gr 25 1.005. It was prep by reacting ethyl vinyl ether with 48% hydrogen peroxide and sulfuric acid (Ref 3), by heating 1,1-diehtoxyethane with 100% hydrogen peroxide at 70° (Ref 4) or by heating β-ethoxy ethyl acetate with 100% hydrogen peroxide at 65° (Ref 4). Spectrophotometric determination (Ref 5)

3-β-Ethoxyethyl-1,2,4-triazole,
CH₃.CH₂.O.CH₃.CH₃—N—NH—CH=N;
mw 141.17, N 29.77%, bp 130° (0.5 torr), nD20 1.4785. It was prep from thiosemicarbazide and β-ethoxypropionyl chloride, followed by nitrous acid oxidation of the intermediate chlo (Ref 2)

4-β-Ethoxyethyl-4H-1,2,4-triazole,
CH₃.CH₂.O.CH₂.CH₃—N—CH=N—N=CH;
mw 141.17, N 29.77%, bp 145–9° (0.05 torr). It was prep via the thiosemicarbazide route (Ref 3), as in preceding item

1-Ethoxy-2[1'-hydroxy-1',4'-dimethyl-pentene-4'-]ethine,
C₆H₅CH₂.C(CH₃).CH₂.CH₂.C(CH₃)OH.CICOC₂H₅;
mw 182.26, bp 82–84° (1 torr), sp gr 0.9258, nD20 1.4635. This product was prep by Arens & Modderman (Ref 2) in the course of their work on synthesis of a lower homolog of citral and of pseudionane. Severe explosions were produced during the distillation of the crude product if it had been stored for 1 night or longer. No expls accompanied distillation of freshly prep batches

1-Ethoxyethyl-3,5-dinitro-1,3,5-triazacyclohexane or 1-(Ethoxyethyl) hexahydro-3,5-dinitro-5-triazine,
EtO.CH₂.N.CH₂.N(NO₂)CH₂.N(NO₂)CH₂;
mw 235.20, N 11.90% (NO₂), mp 118–19°. It was prep by nitration of hexamine dinitrate at -28 to -60° followed by reaction with cold alc; readily nitrated to the 1,3,5-trinitro compound. It was also prep by reacting alc with 1-acetoxyethyl-3,5-dinitro-1,3,5-triazacyclohexane (Ref 2)

**3-(Ethoxymethyl)-hexahydro-1,5-dinitro-1,3,5(1H)-triazepine,**

(CH₃).CH₂.O.CH₂=CH₂.N—CH₂.N(NO₂)CH₂.CH₂.N(NO₂)CH₂; mw 249.23, N 11.24% (NO₂), mp 166.2--166.4°. It was prepd from 1-acetoxymethyl-3,6-dinitro-1,3,6-triazacycloheptane by boiling with alc (Ref 2) and by mixing N,N'-dinitroethylene-diamine with formalin, then adding alc and ammonium acetate (Ref 3)


**Ethoxo-MSX.** Code name for 7-Ethoxy-2,4,6-trinitro-2,4,6-triazahexanate, described under 7-Ethoxy-2,4,6-triazahexanate and Derivatives

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**Ethoxy-naphthalene and Derivatives**

**1-Ethoxy-naphthalene,**

[Diagram]

mw 173.04, mp 5.5°, bp 276.4° (760 torr), 160° (19 torr), 106° (2 torr), sp gr 1.058, nD 1.6035, nD 1.5951. It was prepd by refluxing α-naphthol with ethyl bromide in alcoholic KOH (Ref 1)

**1-Ethoxy-2,4,5-trinitronaphthalene,**

[Diagram]

mw 307.22, N 13.68%, yel ndls, mp 148°, sol in HAc. It was prepd by nitration of the parent at 0° (Ref 2)

**2-Ethoxy-naphthalene,**

[Diagram]

mw 173.04, pltls, mp 35°, bp 282° (760 torr), 146° (12 torr), sp gr 1.0615, nD 1.5975, sol in alc, eth, petr eth, carbon disulfide & toluene. It was prepd by same method as the 1-ethoxy-deriv

**2-Ethoxy-1,6,8-trinitronaphthalene,**

[Diagram]

mw 307.22, N 13.68%, mp 186°. It was prepd by nitration of 2-ethoxynaphthalene or displacement by NaN₃ on the 2-Cl or 2-Br-nitro naphthalenes


**2-Ethoxy-7,8-dinitroso-trinitronaphthalene,**

mw 365.22, N 19.32%, OB to CO₂—81.1%, yel ndls, mp 167°, sol in benz. It was prepd from 7,8-dinitroso-x,x,x-trinitro-2-oxynaphthalene Ag salt and EtI (Ref 2). The Ref gives the following structure, –(C(7)=N—O—O=N=C(8))—, for the dinitroso section of the new compound

*Refs:* 1) Beil 8, 300 2) R. Nitzki & T. Knapp, Ber 30, 1121 (1897)

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**Ethoxy-pentane and Derivatives**

**Ethoxy-pentane,** C₁₀H₁₃.C(O₂H₃) ; mw 116.21, bp 119--20°. It was prepd by reacting ethoxycetyl chloride and butyl zinc iodide in benz

**1,1,1-Trinortro-2-ethoxy-pentane (TNEP),**

[Diagram]

OC₂H₅ ; mw 251.20, N 16.71%, OB to CO₂—86.1%. This expl compd has been prepd by reaction of butyraldehyde, ethanol & nitroform: C₃H₇.CH.OH + H(NO₂)₃ + C₂H₅.OH → TNEP + H₂O; and by the simpler acetal reaction: CH₃.CH₂.CH₂.CH(O₄H₅)₃ + HCN → TNEP + C₂H₅.OH (Ref 3)


**Ethoxyphenylaminotetrazole.** See under AMINOETHOXY-PHENYL-TETRAZOLES in Vol 1 of Encycl, p A202-L
Ethoxyphenylarsinic Acid and Derivatives

4-Ethoxyphenylarsinic Acid,
\( \text{C}_8\text{H}_8\text{O}_2\text{AsO(OH)}_2 \); mw 246.10, wh prisms, mp 185° (H₂O). It was prep'd by diazotization of p-phenetidine and Na₂AsO₃ in alcoholic soln (Ref 2)

3,5-Dinitro-4-ethoxyphenylarsinic Acid
\( \text{C}_8\text{H}_8\text{O}_2\text{As(OH)}_2\text{(NO}_2\text{)}_2 \); mw 336.09, N 8.33%, OB to CO₂ - 71.4%; wh crys, mp - explodes at 275°, sol in alc & hot water. It was prep'd by nitration of the parent (Refs 2 & 3)


Ethoxyphenyltetrazole and Derivatives

p-Ethoxyphenyltetrazole,
\( \text{p-ETO-C}_8\text{H}_8\text{N}_2\text{N}_2\text{N}_2\text{N} = \text{CH} \); mw 190.21, N 29.46%. It may be considered as the parent compd of its Azido deriv, although not used to prep it

p-Ethoxyphenyltetrazoloxidide or Azido-p-ethoxyphenyltetrazole,
\( \text{p-ETO-C}_8\text{H}_8\text{N}_2\text{N}_2\text{N}_2\text{N} = \text{C(N}³\text{)} \); mw 231.22, N 42.41%, mp 72°(dec 140°), plts (from alc), ndls (from water), sol in alc & eth. It was prep'd from p-ethoxyphenyl thiourea, NaN₃ and PbcO₃ to get the aminotetrazole (mp 197°), followed by conversion of the amine to an azide; the intermediate nitrosamine has mp 117°(dec) and the hydrzone, mp 158°(dec)


Ethoxyphenylurethane and Derivatives

p-Ethoxyphenylurethane,
\( \text{p-ETO-C}_8\text{H}_8\text{N} = \text{HCO}_2\text{Et} \); mw 209.25, ndls or plts (from alc), mp 93.5-94°, sol in alc, eth, chlf, benz & HAc. It was prep'd by reacting ethyl chloroformate with p-phenetidine in alc or benz (Ref 1)

2,3,6-Trinitro-4-ethoxyphenyl urethane,
\( \text{p-ETO-C}_8\text{H}(\text{NO}_2)_3 = \text{NHCO}_2\text{Et} \); mw 345.05, N 12.18%(NO₂), OB to CO₂ - 88.1%, yel ndls (from alc), mp 211-212°(dec), 218-19°(Ref 3), sol in alc, eth, benz, HAc & acetone. It was prep'd by boiling the parent with nitric acid (Ref 2) or by warming N-nitro-N-ethyl-N'- (2,3,6-trinitro-4-ethoxyphenyl)-urea in alc (Ref 3)


Ethoxyquinonediazole and Derivatives

Ethoxyquinonediazole, \( \text{C}_8\text{H}_8\text{N}_2\text{O}_2 \), may be considered as the parent compd of its nitro derivs although not used to prep them

4-Ethoxy-3,6-dinitro-o-benzoquinonediazole(1),
\[
\begin{array}{c}
\text{H}_8\text{C}_8\text{O} \\
\text{N}_2\text{O}_2 \\
\end{array}
\]

mw 254.16, N 22.04%, OB to CO₂ - 81.9%; or prisms (from acet ac), mp 186°. It was prep'd by diazotizing 2,3,5-trinitro-4-aminophenote (Ref 2)

3(?)-Ethoxy-5,6-dinitro-o-quinonediazole,
\( \text{C}_8\text{H}_8\text{N}_4\text{O}_4 \); mw 254.16, N 22.04%, OB to CO₂ - 81.9%, yel plts (from alc), mp 165°(dec), expl on rapid heating; sol in alc, HAc & EtAc.

It was prep'd by heating the 3,5,6-trinitrobenzoquinone-(1,2)-diazide-(2) in alc (Ref 3)


5-Ethoxytetrazole, \( \text{C}_5\text{H}_8\text{O}_2\text{N}_3\text{N}_2\text{N} = \text{N} \)

(location of two double bonds and one hydrogen atom within the ring varies with desmotropic isomerism), mw 114.11, N 49.10%, ndls (from benz), mp 98°, sol in w, eth, alc & EtAc. It was prep'd from HN₃ and dimethyl azodicarbonatate. Silver salt expl on heating

Refs: 1) Beil 26, 237 2) R. Stollé & G. Adam, Ber 57, 1658(1924)
Ethoxythiophene and Derivatives

2-Ethoxythiophene,

\[
\begin{array}{c}
\text{S} \\
\text{OC}_2\text{H}_5 \\
\end{array}
\]

mw 128.19, bp 56° (13 torr), sp gr^27 1.075, nD^20 1.5116. It was prep’d by reacting 2-iodothiophene with CuO and NaOEt in EtOH under reflux (Ref 3).

3,5-Dinitro-2-ethoxy-thiophene,

\[
\begin{array}{c}
\text{O}_2\text{N} \\
\text{S} \\
\text{OC}_2\text{H}_5 \\
\end{array}
\]

mw 218.19, N 12.84%, yel ndls, mp 94–95°. It was prep’d by boiling ethanol with the 2-Cl compd and sodium bicarbonate. The 2-Cl was made by a two stage nitration of 2-chlorothiophene (Ref 2). Refs: 1) Beil – not found 2) C.D. Hurd & K.L. Kreuz, JACS 74, 2969 (1952) & CA 48, 9355 (1954) 3) J. Sicic, JACS 75, 3699 (1953) & CA 48, 10726 (1954)

Ethoxytriazahexapenta and Derivatives

1-Ethoxy-2,4,6-triazahexapenta,

\[
\begin{array}{c}
\text{H}_2\text{C}.\text{NH}.\text{CH}_2.\text{NH}.\text{CH}_2.\text{NH}.\text{CH}_2(\text{OC}_2\text{H}_5) \\
\end{array}
\]

mw 147.22, N 28.54%. Not found in open literature Refs: 1) Beil – not found 2) CA – not found

1-Ethoxy-2,4,6-trinitro-2,4,6-triazahexapenta,

code named MSX,

\[
\begin{array}{c}
\text{H}_2\text{C}.\text{N}.\text{CH}_2.\text{N}.\text{CH}_2.\text{N}.\text{CH}_2(\text{OC}_2\text{H}_5) \\
\text{NO}_2 \\
\text{NO}_2 \\
\text{NO}_2 \\
\end{array}
\]

N 14.89%, OB to CO₂ –68.1%. It was prep’d from reaction of 3-Me-1,5-dinitro-5-triazine with nitric acid, titration with Et₂O and refluxing with fused NaAc in HAc (Ref 2); no props given. Ref 3 mentions a UV spectrum Refs: 1) Beil – not found 2) F. Chapman, P.G. Owsen & D. Woodcock, JChemSoc 1949, 1647–48 & CA 44, 1413 (1950) 3) R.N. Jones & G.D. Thorn, CanJRes 27B, 831 (1949) & CA 44, 2848 (1950)

Ethylacetamide and Derivatives

**Ethylacetamide**, CH₃.CO.NH-CH₂.CH₃; mw 87.12, N 16.08%, bp 205°, 104–5° (18 torr), sp gr^25 0.942, sol in water & alc. It was prep’d from ethyl acetate and ethylamine, ethylisocyanate and acetic acid (Ref 1)

N-(2,2-Dinitroethyl)acetamide,

CH₃.CO.NH.CH₂.CH(NO₂)₂; mw 177.12, N 15.81%, OB to CO₂ –58.7%, mp 58–9°. It was prep’d by removal of one –NO₂ from N-(2,2,2-trinitroethyl)-acetamide with KI & CH₃OH followed by H₂SO₄ at 0°C (Ref 7)

N-(2,2,2-Trinitroethyl)acetamide,

H₃.C.CO.NH.CH₂.C(NO₂)₃; mw 222.115, N 25.23%, OB to CO₂ –28.8%, wh ndls, mp 82–84° (Ref 2 & 3), 89–90° (Ref 5), 91–92° (Ref 6). It was prep’d from nitroform and N-methylacetamide (Ref 5 & 6). Impact sensitivity to a 2.5kg hammer is 35 cm (Ref 6)

N-Nitro-N-(2-dinitroethyl)acetamide,

CH₃.CO.N(NO₂)₂.CH₂.CH(NO₂)₂; mw 222.15, N 25.23%, OB to CO₂ –28.8%, mp 73–74°. It was prep’d from N-(2,2,2-trinitroethyl)acetamide by removal of one –NO₂ followed by nitration of the amide N (Ref 7)

N-(2,2,2-Trinitroethyl)azidooacetamide,


n-Ethylacetanilide (Äthylacetanilid, in Ger) (Ger trade name Manno)
to slightly reddish crystals; mp 54.5\(^{\circ}\), more difficultly subliming than camphor, but easier than Centraline; bp 258\(^{\circ}\) (731 torr) for pure and 246–248\(^{\circ}\) for technical; fl p 124\(^{\circ}\)C; sol in water & ether. It is fairly stable against acids and alkalis in cold, but can be saponified on heating for several hours with concd alcoholic KOH. It can be prep'd by reacting ethyl iodide with sodium acetanilide in xylene.

Since it is a good gelatinizer for Collodion Cotton, it was used in Geman exps and proplnts, replacing camphor (Ref 4)

\[
\text{4-Nitro-N-ethylacetanilide (Nitromannol),} \\
\text{O}_2\text{N.C}_6\text{H}_4\text{N} \text{C}_2\text{H}_5 \\
\text{OC.C}_6\text{H}_5; \text{mw 208.22, N 13.45\%,} \\
\text{wh ptlds, mp 117.5\(^{\circ}\), sol in alc & benz.}
\]

It was prep'd by nitration of the patent with nitric acid of sp gr 1.52 (Ref 2) or with nitric acid (sp gr 1.48) in concd sulfuric acid (Ref 3)


**ETHYL ACETATE AND DERIVATIVES**

**Ethyl Acetate (Et Acet) or Acetic Ester (Acetic Ether) (Essigester in Ger), CH₃COO.C₂H₅;**

mw 88.8; colorless, pleasant smelling liquid; sp gr 0.901 at 20/4\(^{\circ}\); fl p –83.6\(^{\circ}\) (–82.4\(^{\circ}\)), bp 77.2\(^{\circ}\); fl p –2\(^{\circ}\) (25\(^{\circ}\)F); coeff of expansion per 1\(^{\circ}\)C 0.00133; heat of combstn at Cₚ 536.9 kcal/mole; heat of formation –110.72; sol sol in w (8.15g/100ml at 15\(^{\circ}\)C), miscible with alc or ether; 100ml of ethyl acetate dissolves about 3.5ml of w at 25\(^{\circ}\). It can be prep'd by heating acetic acid with ethanol in presence of sulfuric acid, followed by distillation.

Ethyl Acetate is irritating to mucous surfaces particularly the eyes, gums and respiratory passages, and is a mild narcotic. Therefore, its recommended maximum allowable concentration is 400 parts per million. Repeated and chronic exposures should not be allowed (Ref 6)

Ethyl Acetate is a good solvent for all Nitrocelluloses and has been used by A. Nobel, in prep'n of Gelatin Dynamites and then in prep'n of smokeless proplnts. It can be used in mixts with acetone as in prep'n of French "Poudre T", but use of straight acetone is unadvisable because it produces brittle colloids (Ref 3, p 87)

Possibilities of transporting NG in ethyl acetate are discussed in Ref 4. Prep'n, props, uses and shipping are discussed in Ref 5


EtAcet is usually delivered in 55-gallon metal drums, for noncorrosive materials, such as covered by FedSpec PPP–D–729

Specification requirements and tests for EtAcet are:

1. **Appearance** – shall be clear and free from sediment and suspended matter
2. **Odor** – shall have characteristic "banana oil" odor and shall leave no residual odor when tested accdg to FedTestMethodStd No 141a, Method 4401, Sept 1, 1965

Procedure: Note the odor immediately upon opening the container. In addition, dip a strip of heavy filter paper (Whatman No 2 or equal) into container with EtAcet and hang the test strip on a suitable support. Place it in a draft-free area away from any hoods and under atm condition to allow EtAcet to dry. Examine the test strip at suitable intervals for the normal "banana oil" odor. The presence of any additional odor shall be regarded as indicating the presence of an adulterant
3. **Color** – not darker than No 10 on the platinum-cobalt scale as prescribed by ASTM Method D1209. This method is described in this Vol, under "Ether, Diethyl: US Armed Forces Specification Requirements and Tests," pp E185 to E188
4. Specific Gravity — min 0.883 & max 0.888 at 20°/20° (68°/68°F) shall be detd by any convenient method that is accurate to the third place (such as by pycnometer, described in Vol 3 of Encycl, pp D69 to D71, under Density and Specific Gravity)

5. Acidity — free acid as acetic acid 0.01% by wt. This is equivalent to 0.093 mg of KOH per gram sample. Use Procedure 4.3.3 of Spec MIL-E-463B described here under ETHANOL, Analytical Procedures

6. Water Content — 0.20% by wt. This limit insures that the material is miscible without turbidity with 19 volumes of 99% heptane at 20°. Determination is conducted by Karl Fischer Method, as described in ASTM D1364 and here as Spec MIL-E-463B, Procedure 4.3.7 under ETHANOL, Analytical Procedures

7. Distillation Range at 760mm — initial boiling point 70° and dry point 80°C. Use any standard distillation apparatus

8. Nonvolatile Matter — 0.005 g per 100 ml. Pipet 100 ml of EtAcet into tared 150 ml evaporating dish (previously heated in an oven at 105°±5° to constant wt and cooled in a desiccator), and evaporate the contents over a steam bath almost to dryness. Then heat the dish with contents in an oven at 105°±5° for 1 hour, cool in a desiccator and weigh. Return the dish with contents to the oven for 30 mins, cool and reweigh. Repeat, if necessary, until the wt is constant or within 0.1 mg of the last weighing

9. Ester Content (as Ethyl Acetate) — min 85.0 & max 88.0%. It shall be detd in accordance with ASTM D1617—69, described in Annual Book of ASTM Standards, Part 20 (1972), 736—39

*Note 1:* The method described in ASTM D1617—69 applies not only to EtAcet, but also to other esters, such as n-buty1 acetate, isopropyl acetate, acetate ester of ethylene glycol monooethyl ether, sec-butyl acetate, amy1 acetate, dibutyl phthalate and isobutyl acetate

*Note 2:* Org chlorides, nitriles and amides interfere. Ketones and aldehydes interfere only slightly with this procedure

In this method the sample is reacted with a measured excess of Ag KOH, using isopropanol as a mutual solvent, if required (but not for EtAcet). The amp of KOH consumed, which is detd by titrating the excess with std mineral acid, is a measure of the ester originally present. Since this det is based on acidimetric titration, a suitable correction should be applied if the acidity of the sample exceeds the limit of spec.

**Apparatus:**

a) Pressure Bottle — 200 to 350 ml capacity made from heat-resistant glass. Bottles of this type, equipped with lever-type closures, can be obtd from the B. Preiser Co, Charleston, WV.

b) Container for Pressure Bottle. A metal safety enclosure with hinged top and perforated bottom, a strong synthetic fabric or canvas bag, or a safety shield can be used

c) Ampoule — 1 or 2 ml capacity

*d) Weighing Pipet — Lunge or similar

**Note 3:** It was found during WWII in the laboratory of Keystone Ordnance Works, Meadville, Pa that Berl Pipet and Modified Weighing Pipet were more convenient to work than Lange's (See Figs Et 11 and Et 12)
e) Erlenmeyer Flasks – 250ml capacity, Pyrex with glass stoppers
f) Buret – 50ml capacity
g) Boiling Water Bath

Reagents:
Reagent grade chemicals, such as conforming to the ACS Specifications shall be used and water conforming to the Specifications for Reagent Water, ASTM Designation D1193
a) Hydrochloric Acid, Standard (0.5N). Prep and standardize against 1.0N KOH std reagent to 4 significant figures. Used when isopropanol is added as solvent (See operation c under Procedure)
b) Isopropanol – 99% (Not required for EtAcet)
c) Phenolphthalein Solution – 1g of phph in 100ml methanol
d) Potassium Hydroxide, Standard Solution (1.0N) – 66g of KOH pellets dissolved in reagent water and diluted to 1 liter (Do not use NaOH soln as a substitute)
e) Sulfuric Acid, Standard (0.5N). Prep and standardize to 4 significant figures. Used when isopropanol is not added as solvent (See opn c, under Procedure)

Procedure:

a) Prepare two Erlenmeyers for blanks and two for samples tested in cold. For testing at 98° prep two pressure bottles
b) Into each of the flasks and pressure bottles (except those intended for blanks) carefully introduce 25ml of 1.0N KOH soln, using the same calibrated pipet for each transfer
c) This opn prescribes add to each flask the amt of isopropanol prescribed in Table I of ASTM D1617-69, but such addn is not required for ethyl acetate or acetate ester of ethylene glycol monoethyl ether
d) Stopper two of the flasks and two pressure bottles of opn b and set them aside for the blanks. Into each of the other two flasks and two bottles, introduce sealed ampoules, each contg not more than 0.016 mol of the ester, weighed to the nearest 0.1mg. In case of EtAcet, the wt must be not higher than 88.10 x 0.016 = 1.4096g. The flasks and bottles must be strong enough to withstand the next opn of breaking ampoules
e) Introduce to each of the two sample flasks and two bottles several of fire-polished 8-mm glass rods, stopper and shake the flasks and bottles vigorously to break the ampoules
f) Reaction at 98°C. Enclose each of the four pressure bottles securely in a protective container (listed as opn b, under Apparatus) to restrain fragments of glass should the bottle rupture. Place the samples and blanks as close together as possible in the boiling water bath maintained at least at 98°C for 30 minutes. The amt of water in the bath must be sufficient to just cover the liquid in the bottles. Remove the bottles from the bath and allow to cool to RT. Then remove the bottles from the protective containers and uncap the bottles carefully to release any pressure. Continue as prescribed in opn h
g) Reaction at Room Temperature. Allow the two Erlenmeyers with blanks and two with samples to stand for 30 minutes at RT and then proceed as in opn h
h) If a white ppt develops in the sample bottles (heated at 98°) or in sample Erlenmeyers left for 30 mins at RT, add sufficient amt of water to dissolve the ppt. This amt shall be the same for each bottle or Erlenmeyer, contg samples and blanks. Add 6 to 8 drops of the phph indicator to each flask or bottle and titrate with std 0.5N sulfuric acid soln just to the disappearance of the pink color
i) Measure the temp of the acid and, if it is not the same as it was at the time the reagent was standardized, apply a correction to the normality. Use a ΔN/ΔT of 0.00014 per °C in making the correction
j) Calculation
Calculate the percentage of ethyl acetate as follows:

\[ \% \text{EtAcet} = \frac{(B-A) \cdot C \cdot F}{W} \times 100 \]

where:

A = mls of 0.5N sulfuric acid required for titration of sample, as described under opn h
B = average mls of 0.5N sulfuric acid required for titration of the blanks
C = normality of acid corrected for temperature
F = factor for EtAcet specified in Table II as 0.0881, and
W = grams of sample used in each bottle or Erlenmeyer

Note 4: If the acidity of the ester exceeds 0.01% by wt as free acetic acid (See opn 5 of FedSpec TT-E-751C), a suitable correction must be applied to the ester value
k) Report the results to the nearest 0.1%. Duplicate dems which agree within 0.38% absolute are acceptable for averaging
Ethyl Acetate, Use in French Propellants and Its Determination in Them

According to Dalbert & Tranchant (Ref 1), ethyl acetate has been used as a volatile gelatinizer in some French smokeless propellants, such as T & Tbis of the Pouletier de Sevan.

Estimation of EtAcet in these propellants can be conducted by the following method:

Treat 20 g of propellant with 120 ml of 36% Be NaOH (40% aqueous soln) and 280 ml of dist'd water. This decomposes EtAcet into ethanol and Na acetate. Distill off about 150 ml of liquid into a receptor cooled in ice and filter the distillate. Add to the distillate, with cooling and swirling, about 40 ml of concd sulfuric acid and exactly 30 ml of the soln contg 48.45 g potassium dichromate per liter of sulfuric acid. Heat on a water bath for 20 minutes in order to oxidize the ethanol, cool, transfer to a 250 ml volumetric flask and adjust to volume by adding some sulfuric acid. Pipet out 25 ml of soln and titrate the excess of dichromate by means of KI and 0.1N sodium thiosulfate soln.

Then titrate a blank prep by mixing the same ingredients as above except that the 150 ml distillate is replaced by 150 ml of dist'd water

Calculation:

\[ \text{Weight of EtAcet in Propellant} = 0.0352 \times 30 \times \frac{N - n}{N} \]

where:

- \( N \) = ml of sodium thiosulfate soln required for blank, and
- \( n \) = ml of the same soln required for sample (Ref 1)

In Ref 2 is described analysis of industrial EtAcet liable to contain water, ethanol and ethyl formate with traces of acidity, whereas in Ref 3 is described a precise method for determ of acidity in EtAcet

In Ref 4 is described a rapid method for determ of the amount of EtAcet & ethanol in their mixtures with water, accdg to the density and water content as deterd by the Fischer Method


Ethyl Acetate, Azido- and Nitroglycerine Derivatives

Ethyl acetate Azide, Ethyl azidoacetate Acid or Azidoacetate Acid Ethyl Ester, \( \text{N}_3\text{CH}_2\text{CO.O.C}_2\text{H}_4 \); mw 129.12, N 36.41%, chlf odor, bp 74-75°C (23 torr), 62°C (12 torr), 45°C (2 torr), sp gr20 1.127, sp gr20 1.118, nD20 1.4341. It was prepd in 1908 (Refs 2 & 3) by refluexing ethyl azidoacetate with AgN\(_3\) or ethyl chloroacetate with NaN\(_3\).


Ethyl azidotetrazide (Bistriazol-oessigsaure-ethylster in Ger), \( \text{N}_3\text{CH}_2\text{CO.O.C}_2\text{H}_4 \); mw 170.13%, N 49.4%, OB to CO\(_2\) -84.7%, colorless, odorless, liquid, bp 70-72°C (about 2 torr), sp gr20 1.222, sp gr20 1.220, nD20 1.4640. It was prepd in 1908 by refluexing ethyl dichloroacetate with NaN\(_3\) (Ref 3). It tended to exp in cont with concd sulfuric acid. It was considered too dangerous to explore further


2-Azidoethoxy-acidacetate, \( \text{N}_3\text{CH}_2\text{CO.O.CH}_2\text{CH}_2\text{N}_3\); mw 170.13, N 49.4%, OB to CO\(_2\) -84.7%, bp 115°C (8.5 torr), 90°C (1.1 torr), nD20 1.4798. It was prepd in 1908 by heating azidoacetyl chloride with 2-azidoethanol at 100°C (Ref 2), and in 1964 by reacting chloroethyl chloroacetate with NaN\(_3\) in dimethylformamide (Ref 3). It detonates mildly when placed on a hot plate; apparently reacts vigorously with concd sulfuric acid and hot KOH soln

Ethyl nitroacetate, \(O_2N\cdot CH_2\cdot CO\cdot OC_{6}H_{5}\); 
mw 133.10, N 10.53%; colorless liq, sp gr 1.199
at 20/4\(^\circ\), \(n^D_2\) 1.4247, bp 105-0\(^\circ\) at 25 mm; v s l
sol in w, sol in alc, insol in eth. It can be
preped by the action of KOH on nitromalic acid diethyl ester
Refs:  1) Beil 2, 225, (100) & (207)  2) A. Wahl,
CR 132, 1053 (1901)

Ethyl dinitroacetate, \((O_2N)_2\cdot CH\cdot CO\cdot C_{6}H_{5}\); 
mw 178.10, N 15.72%, OB to CO\(_2\) -44.9%, colorless
oil, bp 50-54\(^\circ\) (0.05 torr, Ref 4) and 40\(^\circ\) (0.5
torr, Ref 5), \(n^D_2\) 1.4336, sp gr 0.1.369. It was
prepd by ambient nitration of monoethoxylmalinate
(Ref 2).
Refs:  1) Beil 2, 228, (100)  2) L. Bouveault
& A. Wall, CR 136, 159 (1903)  3) W. Kissingler
& CA 53, 15951 (1959) (Prepn)  4) C.A. Parker,
USP 2925433 (1960) & CA 54, 11480 (1960)(Prepn)
5) Ibid (3) 24, 666-8 (1959) & CA 54, 18335 (1960)
(Prepn)

Ethyl trinitroacetate, \((O_2N)_3\cdot CH\cdot CO\cdot OC_{6}H_{5}\); 
mw 223.10, N 18.83%, OB to CO\(_2\) -17.9%
Refs:  1) Beil, not found  2) CA, not found

2,2,2-Trinitroethyl Acetate,
CH\(_3\)CO\cdot CH\(_2\)\cdot C(NO\(_2\))\(_3\); mw 223.10, N 18.83%,
OB to CO\(_2\) -17.9%, colorless oil, fr p 26\(^\circ\)
(Ref 6), bp 85-95\(^\circ\) (in vacuo) (Ref 3). Ref 2
gives 118\(^\circ\) at 4 mm; does not decom
preciably when heated up to 140\(^\circ\); s l sol in w. It
can be prepd by treating trinitroethanol with
acetyl chloride.

Trinitroethanol Acetate is stable at RT
and insensitive to impact (does not deton by
5kg wt falling from one meter height).

It is a good gelatinizer for NC and could be
used in manuf of smokeless proplnts or of dyna-
mite type expls if its price were less expensive.
Refs:  1) Beil, not found  2) N.S. Movans
& R.I. Zelinski, JACS 72, 5329-30 (1950) &
CA 45, 4642g (1951)  2a) M. Hill, NAVORD
Rept 2245 (1951) (Prepn & prods)  3) H.
Fichouolle & A. Gay-Lussac, MP 34, 121-23
(1952) & CA 48, 4839-39 (1954)  4) S.S.
Novikov, G.A. Shvekhgeimer & N.F. Pyatokov,
IzvestAkadNau, OtdKhimNauk 1961, 375 & CA 55,
1977 (1961) (Prepd by heating the alcohol with
ethoxyacetylene and HCl, bp 90\(^\circ\), \(n^D_2\) 1.4528,
sp gr 1.4743 at 20\(^\circ\))  5) M.E. Hill, USP

322375 (1965) & CA 64, 6570 (1966) (Prepd by
reacting the alcohol with acetyl chloride and
a Friedel-Crafts catalyst in 85% yield)
6) N.D. Lebedeva, V.L. Ryadnenko & I.N.
Kuznetsova, ZhFizKhim 1968, 42 (7), 1827
(Russ) & CA 69, 90540 (1968) (sp gr 1.4794 at
20\(^\circ\), bp 1.4484 at 20\(^\circ\), bp 1.645\(^\circ\), mp 26\(^\circ\), heat
of combustion 1982 (no units given in CA)
7) L.T. Eremenko, N.G. Zhitomirskaya & G.V.
Oreshko, IzvAkadNaukSSR, SerKhim 1969, (12),
2674-87 (Russ) & CA 72, 84439-41 (1970)
(IR spectrum)

Trinitroethoxyacetic acid,
N\(_3\)CH\(_2\)COO.CH\(_2\)C(NO\(_2\))\(_3\), mw 264.11, N 15.91%
(NO\(_2\)), OB to CO\(_2\) -12.1%. Nothing in open
literature. See Ref 3. It is an explosive.
Refs:  1) Beil, not found  2) CA, not found
3) US Rubber Co QuartRept No 25 on Contr Nos
10129 & 12663, Nov 1, 53 to Feb 1, 54 (1954), p 8

Dinitroethyl dinitroacetate,
(O\(_2N\))\(_2\)CH.COO.CH\(_2\)C(NO\(_2\))\(_3\), mw 268.10,
N 20.89%, OB to CO\(_2\) 0.0%. Not known in open
literature.
Refs:  1) Beil, not found  2) CA, not found

Dinitroethyl dinitroacetate,
(O\(_2N\))\(_2\)CH.COO.CH\(_2\)C(NO\(_2\))\(_3\), mw 313.0, N
22.36%, OB to CO\(_2\) +12.8%; solid. Not known in
open literature.
Refs:  1) Beil, not found  2) CA, not found

Dinitroethyl trinitroacetate,
(O\(_2N\))\(_3\)C.COO.CH\(_2\)C(NO\(_2\))\(_3\), mw 358.09, N
23.47%, OB to CO\(_2\) +22.3%. Not known in open
literature.
Refs:  1) Beil, not found  2) CA, not found

Ethylacetic Acid. See Butyric Acid in Vol 2
of Encycl, p B391ff

Ethylacetoacetic Acid and Derivatives
Ethylacetoacetic Acid, Ethylacetoacetate or
Acetoacetic Ester,
CH\(_3\)CO.CHO.COO.C\(_3\)H\(_6\); mw 130.14; colorless
liq of fatty odor, sp gr 1.025 at 20/4\(^\circ\); mp -45\(^\circ\)
(-80\(^\circ\)), bp 180\(^\circ\) at 755mm; s l sol in w; miscible
with alc, eth & chl. It can be prepd by the
action of metallic Na on ethylic acetate with sub-
sequent distillation. Used in org synthesis,
pharmaceuticals, dopes, plastics, etc

Ethylacetocetic Acid Diazide, Ethyl-a,a-bistri-oxoacetocetate or Diozidoethylacetoacetate,
CH₅CO.CN₃₂,N=COO.C₂H₅; mw 212.16, N 39.68%.
mw 212.16, N 39.68%, fuming liq. bp 81-82°(0.9 torr). It was prepd by action of NaNO₃ on the a,a-dichloroanalogue
in aq alc (Ref 2).
It is an explosive compd; in one of the attempts to det its %N, an expln resulted

Ethylactonate. Same as Methyl-n-propylketone
or 2-Pentanone, described in Beil 1, 676 and in CondChemDict (1961)

Ethylacetonitrile Acid and Derivatives
Ethylacetonitrile Acid or EthylNitrocetaldoxime, CH₃CN(O₂)=NO.C₂H₅, mw 132.12, N 21.20%. Not known in open literature
Refs: 1) Beil - not found  2) CA - not found

1,1-Dinitroethyl-acetonitrile Acid; N(1,1-
Dinitroethyl)-1-nitroacetaldoxime or 2,5-
Trinitro-3-aza-4-oxa-hexene-2,
CH₃C(NO₂)=N-O=C(NO₂)₂CH₃ or, possibly, CH₃CN(O₂)=NO.C₂H₅, mw 222.11, N 25.22%. OB to CO₂ -28.8%, mp 121.2-121.6°,
heat of combustion, H₂, 544.8kcal/mol. It was prepd from 1,1-dinitroethane and its ammonium salt (Ref 2)
Refs: 1) Beil, not found  2) J.S. Belew, C.E. Grabiel & L.B. Clapp, JACS 77, 1110-14(1955)  
  & CA 50, 1648(1956)  3) A.J. Young et al., IndEngChem 48, 1375-8(1956) & CA 50, 16274
1959, 1480-1 & CA 54, 1284(1960)(Prepn)

Ethylacetylene and Derivatives
Ethylacetylene or 1-Butyne, C₂H₃:C=CH; mw 54.09; colorless, flammable gas, available in commerce in liquefied form; sp gr 0.669 at 0/0°,
fp -125.8°, bp 8.7°(8.3°); fl p (Tag open cup) <20°F; insol in w; sol in alc & eeb. It can be prepd by action of potassium on 2,2-dichloro-
butane, or treatment of 2-bromobutene-1 with alcoholic KOH at 100°(Ref 2). It is used as specialty fuel and as an intermediate

1-Nitroethylethylenyne, C₂H₃=C=NO₂; mw 99.09,
N 14.14%, red oil, expl on heating in vacuo or in air, polymerizes on standing. It was prepd by mixing 1-bromo-1-nitro-1-butene with methylamine
Refs: 1) Beil - not found  2) J. Loevenich, J. Koch & U. Pucknat, Ber 63B, 636-46(1930) & CA 24, 3211(1930)

Ethylacrylaidine and Derivatives
N-Ethylacrylaidine, mw 209.29. Not found in
literature. A nitric acid salt is mentioned in
Ref 3. It should be possible to reduce N-
ethylacrylaidone (See following entry)
Refs: 1) Beil, not found  2) CA, not found
3) V. Zanker et al., ZPhysickChem (Frankfurt)
48(3-4), 179-95(1966) & CA 65, 2092(1966)

N-Ethylacridone,

mw 223.28, gr-yel prisms (from alc), mp 159°;
sol in alc. It was prepd by heating potassium
acridone with C₂H₅I at 130-40°(Ref 2)
Refs: 1) Beil 21, 336  2) C. Graebe & K.
Lagodzinski, Ber 25, 1736(1892)  3) B.I.
Mikhant’ev & V.A. Skyatov, ZhurObsdshch-
Khim 26, 784-8(1956) & CA 50, 14760(1956)
(Prepn)

N-Ethyl-2,4,5,7-tetranitroacridone,

(ON)₂C₂H₅(NO₂)₂

mw 403.27, N 13.89%, mp 282°. It was prepd
from heating ethylamine with o,o'-dimethoxy-
m,m'-m'-tetranitrobenzenophene
Refs: 1) Beil, not found  2) C.W. Pohlmann,
RecTravChim 55, 737-52(1936) & CA 30,  
7111(1936)

Ethylacylate and Derivatives
Ethylacrylate, CH₂=CH.COO.C₂H₅; mw 100.11;
colorless liq, sp gr 0.925 at 15°, fp p -72(-75°),
bp 100-01°(99.8°); sol in w (9% by wt);
readily polymerizes. It can be prepd by inter-
action betw ethylene cyanohydrin and ethanol in
dil sulfuric acid, or by oxo reaction of acetylene,
CO and ethanol in the presence of Ni or Co cata-
lyst; used as a chemica intermediate and in
prepn of polymers and acrylic paints
Refs: 1) Bei, 2, 399, (186) & [386] 2) W.
Caspary & B. Tollens, Ann 167, 248 (1873)

Ethyl-2-nitroacrylate, O₂N.CH=CH.CO₂.C₂H₅;
mw 145.11, mp 100–2°. It was prepd by adding
Na.CH₂NO₂ to C₂H₅.O₂C.CH=CH.O, con-
verting the resulting alcohol to a chloride with
PCl₅, and splitting out an internal−CH₂ClCH₂−
group with NaAc
Refs: 1) Bei, not found 2) L.A. Yanovskaya,
R.N. Stepanova & V.F. Kucherov, IzvAkadNauk-
SSSR, SerKhim 1964(11), 2093–5 & CA 62, 7630c
(1965)

2-Nitroethylacrylate, CH₂=CH.CO₂.CH₂(CH₂)₃NO₂;
mw 145.11, mp 100° (5 torr) and ca 50° (ca 0.2
torr), sp gr 1.204 at 25°, nD 1.4510 at 25°. It
was prepd by distillation from a mixture of
medylnylacrylate, 2-nitroethanol, hydroquinone,
toluenesulfonic acid and xylene (Ref 2)
Refs: 1) Bei, not found 2) N.S. Marans &
R.P. Zelinski, JACS 72, 2125-6 (1950) &
CA 44, 8858 (1950) 3) H.J. Roy Jr, USP
2710830 (1955) & CA 50, 5723 (1956) (Purif)
4) J.W. Lawrence & H.F. Bluem, USP 3179644
(1965) & CA 63, 426 (1965) (Prepn)

2-Nitrotoethylacrylate, CH₂=CH.CO₂.CH₂(CH₂)₃ONO
mw 161.11, bp 100–3° (8 torr), sp gr 1.246, nD
1.4500. It was prepd by heating acryl chloride
with 2-nitroethanol in the presence of cuprous
chloride
Refs: 1) Bei, not found 2) N.S. Marans &
R.P. Zelinski, JACS 72, 5330-1 (1950) & CA 45,
4648 (1951)

Trinitroethylicrylate, CH₂:CH.CO.OH.CH₂.C(NO₂)₃;
mw 235.11, N 32.83%; OB −30.6%, bp 80° (2 torr),
νD 1.4640, νD 1.492. It was prepd by heating
together acryl chloride and 2-(trinitro)ethanol
(Ref 1). It has impact sensitivity of 45 with 2 kg
weight (Ref 4)
Refs: 1) Bei, not found 2) H. Feuer, H.H.
Hass & R.D. Lowrey, J OrgChem 25, 2070-1
(1960) & CA 55, 14300c (1961) 3) J. Ville,
MP 42, 21-7 (1960) & CA 55, 18109 (1961)
4) R.H. Saunders, USP 2994714 (1961) & CA 55,
25758g (1961)

Ethyl Alcohol. See ETHANOL in this Vol,
p E154 ff

Ethylalddehyde (Ethanal or Ethylidine Oxide).
See ACETALDEHYDE in Vol 1, pp A14 to A15

Ethylamine. See AMINOETHANE in Vol 1, pp
A199 to A200

Ethylamine-Azide. See Vol 1, p A199

N-Aminoethylacetamide and Derivatives
N-Aminoethylacetamide,
CH₃.CO.NH.CH₂.CH₃.NH₂, mw 102.14; bp
135–40° (2 torr). It was prepd by heating
ethylenediamine with ethyl acetate (Ref 2)

N-(2-Nitroanilino) -acetamide,
CH₃.CO.NH.CH₂.CH₂.NH.NO₂, mw 147.14,
N 28.56%, mp 134-5–135.5°. It was prepd by
treatment of 1-acetyl-3-nitro-2-imidazolidinone
with dil NaOH, followed by a cyclization (Ref 3)
Refs: 1) Bei, not found 2) K.W. Rosensnund,
USP 1926015 (1933) & CA 27, 5339 (1933)
3) M.W. Kirkwood & G.F. Wright, J OrgChem 18,
629-42 (1953) & CA 48, 6968 (1954)

Ethylaminooanisoles and Derivatives
2-Ethylaminooanisole or Ethylanisidine,
C₆H₅.NH.C₆H₄.OCH₃; mw 151.20, oil; bp 117°
at 3mm, 228–9° at 728mm. It may be prepd by
heating at 59° a mixture of o-anisidine and
ethylen bromide
Ref: Bei 13, 364

Dinitroethylaminooanisoles,
C₆H₅.NH.C₆H₄(NO₂)₂.OCH₃; mw 240.19, N
17.49%
3,3-Dinitro-2-ethylenaminooanisole, mp 123°; may
be prepd from 2,3,5-trinitroanisole and ethyl-
amine
Ref: Bei 13, 393
4,6-Dinitro-3-ethylenaminooanisole, mp 148°; may
be prepd from 5-bromo-2,4-dinitroanisole and
Ethylamine
Refl: Beil 13, 424

3,5-Dinitroethyl-2-nitroanisole,
O₂N·N(C₂H₅)₃C₆H₅(NO₂)₂OCH₃; mw 286.20, N 14.68% (NO₂); mp 67°, may be prepd by treating 3,5-dinitro-2-ethylaminoanisole with nitric acid (d 1.52)
Refs: 1) Beil 13, 394 2) J.J. Blanksma, Rec 23, 113 (1904)

Ethyl p-aminoaceto-benzoate or Benzocaine (Anerthesine), C₆H₅·NH₃·COO·C₂H₅; mw 165.19; wh crysts (from alc), mp 91–2°; v sl sol in w; sol in dil acids; less sol in chl, eth & alc; exhibits local anesthetic props when placed on the tongue. It can be prepd by ethylation of p-nitrobenzoic acid, followed by reduction; used in medicine

Ethyl p-amino-p-nitrobenzoate,
H₂N·C₆H₅(NO₂)·CO₂C₂H₅; mw 210.18, N 13.33%
Ethyl 4-amino-2-nitrobenzoate; lt yel ndls, mp 130°; sol in alc, eth; insol in w; may be prepd by refluxing ethyl 4-bromo-3-nitrobenzoate and ethyl 2,4-dinitrobenzoate in abs alc or from 4-amino-2-nitrobenzoic acid and ethyl iodide in alc potash or alc sulfuric acid
Refs: Beil 14, 439 & (583)

Ethyl 4-amino-3-nitrobenzoate; mp 136°; insol in petr eth, sol in usual org solvents; may be prepd by refluxing ethyl 4-bromo-3-nitrobenzoate and alc NH₃ at 150° for 3 hrs; by esterification of 4-amino-3-nitrobenzoic acid with abs alc in sulfuric acid; or by refluxing ethyl 4-ethoxy-3-nitrobenzoate and alc NH₃
Ref: Beil 14, 441

Ethyl p-amino-dinitrobenzoate,
H₂N·C₆H₅(NO₂)₂·CO₂C₂H₅; mw 255.18, N 16.49%
Ethyl 4-amino-3,5-dinitrobenzoate; gold-glimmering leaflets, mp 114°. It may be prepd by esterification of the acid in alc HCl
Ref: Beil 14, 458

Ethylaminocellulose. See Aminoethylcellulose in Vol 1, p A203-R

Ethylaminocellulose Nitrate and Perchlorate
are described in Vol 1, p A204

Ethylamino Compounds. See Vol 1, pp A204 to A209

Ethylaminoaethanol and Derivatives
β-Ethylaminoaethanol or Ethylethanolamine, C₂H₅·NH·CH₂·CH₂OH; mw 89.14, colorless oil, sp gr 0.914 at 20/4°; fr p ?, bp 167–69° at 751mm, d p 160°F; v sol in w, alc & eth; can be prepd from ethyl bromide and excess 2-amino-ethanol at 50–60°; used as solvent and for prepn of nitrated derivs, such as Eth-NENA

Ethylaminoaethanol Nitrate,
C₂H₅·NH·CH₂·CH₂·ONO₂; mw 134.13, N 20.88%; crystals (from methylethylketone), mp 68°, may be prepd by treating 2-ethylaminoethanol with concd nitric acid at −5°

1-(N-Ethyl)-nitrarno-2-ethanol Nitrate; N-(β-Nitroxyethyl)-ethyl nitramine or N-(2-Nitroetoethyl)-ethyl nitramine, code named Eth-NENA,
(C₂H₅)₂·NH·CH₂·CH₂·ONO₂; mw 179.13, N 23.46%, NO₂
OB to CO₂ 67.0; pale yel oil, sp gr 1.32 at 25/4°, dP 1.479 at 25°; fr p 4.0–5.5°, bp ?°. It was prepd by Blomquist & Fiederek (Refs 2 & 3) by nitration of ethylaminoaethanol. For this, ethylaminoaethanol was added dropwise, with stirring, to 98% nitric acid, while maintaining the temperature at 10°; then the resulting mixture was transferred to a dropping funnel and added dropwise, with stirring, to 95% acetic anhydride contg some acetyl chloride
Following reactions took place:

(C₂H₅)₂·NH·CH₂·CH₂·OH → (C₂H₅)₂·(NH₄)⁺ \[\text{HNO}_3\]⁻ + \[\text{C}_2\text{H}_5\]₂·N·CH₂·CH₂·ONO₂

An improved procedure called "two-stage liquid-phase" is described in Ref 4
Ethyl-NENA may be considered as a possible plasticizer for NC in double-base propellants
Refs: 1) Beil, not found  2) A.T. Blomquist & F.T. Fiedorek, OSRD Rept 4134 (1944) & PB
Rept 18867 (1944), pp 44-5 & 118  3) Ibid, USP 248555 (1949), pp 5 & 11-12 and CA 44,
3516-17 (1950)  4) Ibid, USP 2687946 (1954) & CA 49, 4704 (1955)

Ethylaminoethylguanidine and Derivatives
Ethylaminoethylguanidine,
H₂N.CH₃.NH.C(:NC₆H₅)NH₂; mw 130.19, N 43.04%  
Refs: 1) Beil, not found  2) CA, not found
2-Ethyl-1-(2-nitriminoethyl)-3-nitroguanidine,
O₂N.NH.CH₂.CH₂.NH.C(:NC₆H₅)NH₂NO₂; mw 220.19, N 38.19%; may be prepared from 1-
nitro-2-nitrimino-2-imidazoline dissolved in aq EtNH₂ and adjusting the pH to 1 at a tempera-
ture of less than 200  
Refs: 1) Beil, not found  2) A.F. McKay and C. Sandoft, CanJChem 31, 42-7 (1953) &
CA 47, 6765 (1953)  3) A.F. McKay & W.G. Hatton, JACS 75, 963-65 (1953) & CA 48,
2049 (1954)

Ethylaminoethyl-pseudourea and Derivatives
Ethylaminoethyl-pseudourea, mw 131.17
Refs: 1) Beil, not found  2) CA, not found
2-Ethyl-1-(2-nitriminoethyl)-3-nitropseudourea,
NH
||
O₂N.NH.CH₂.CH₂.NH.CN.H.NO₂; mw 221.18,
N 31.67%, mp 133.6-1340; may be prepd by re-
fluxing 1-nitro-2-nitrimino-2-imidazoline with
EtOH for 19 hours
Refs: 1) Beil, not found  2) A.F. McKay &
C. Sandoft, CanJChem 31, 42-7 (1953) &
CA 47, 6765 (1953)

3(β-Ethylaminoethyl)-α-sym-triazole Dipicrate.
See in Vol 1, p A208-R

Ethylaminoguanidine. See Aminoethylguanidine
in Vol 1, p A205-R

Ethylaminimidazoline and Derivatives
Ethylaminimidazoline, H₂C-N-CH₂.CH₃

H₂C-N

C.NH₂

mw 113.16, N 37.13%; may be considered as
a parent compd of Tetratoethyl-nitriminimid-
azole although not used for its prep
1-(2,2,2-Trinitroethyl)-2-nitramino-2,3-imidazole.
H₂C-N-CH₂.C(NO₂)₃

C.NH.NO₂

H₂C-N

mw 293.16, N 33.45%; long, wh ndls, mp 168-690 (decomp); bums
rapidly and readily detonates; may be prepd
from 2-nitramino-1,3-diazao-2-cyclopentane &
nitroform
Refs: 1) Beil, not found  2) US Rubber Co, 5th
Rept (1948-49), p 33 & Summary Rept on Cont
NOOrd 10129, p 3  3) H.A. Hageman, USP
3043848 (1962) & CA 57, 14045 (1962)

Ethylaminonylon and Its Perchlorate. See under
Aminoethylonylon in Vol 1, p A205

Ethylaminophenols and Derivatives
N-Ethylaminophenols or N-Ethylhydroxyanilines,
C₆H₅.NH.C₆H₄.OH; mw 137.18. All three isomers:
α-, β-, and γ- are known and described in the
literature
Refs: 1) Beil 13, 364 (ortho)  2) Beil 13, 408
(meta)  3) Beil 13, 443, (150) & [231](para)

Dinitro-N-ethylaminophenols,
C₆H₅.NH.C₆H₄(NO₂)₂.OH; mw 277.17, N 15.16%(NO₂)
3,5-Dinitro-3-ethylaminophenol. It may be
prepd by nitration of N-ethylbenzoxazoline
with nitric acid, giving the 4,6-dinitro deriv-
ative. Alkaline hydrolysis gives the 3,5-
dinitro phenol derivative
4,6-Dinitro-3-ethylaminophenol, yel ndls, mp
128-29°; sol in hot w; may be prepd from 4,6-
dinitro-3-ethylaminophenol by saponification
with hot alcoholic potash
Refs: 1) Beil 13, (138)  2) G. Wagner & S.
Leisner, Pharmazie 26, 280-2 (1971) & CA
75, 35852 (1970)

Trinitro-N-ethylaminophenol,
C₆H₅.NH.C₆H₄(NO₂)₃.OH; mw 272.17, N 20.29%
2,4,6-Trinitro-3-ethylaminophenol; mp 110°; may
be prepd by exchange with EtNH₂ on either
2,3,4,6-tetranitrophenol or 3-chloro-2,4,6-trinitrophenol in alcohol
Ref: Beil 13, (140)

**Trinitro-N-ethylnitraminophenol**,
C$_5$H$_6$N(NO$_2$)$_3$.C$_6$H(NO$_2$)$_3$.OH; mw 317.18, N 22.08%
2,4,6-Trinitro-3-ethylnitraminophenol; mp 105–60;
may be prepd by treating N-ethyl-N-(2,3,4,6-
tetranitrophenyl)nitramine with boiling water or
by nitration of the trinitroethylaminophenol above
with nitric acid (d 1.52)
Refs: 1) Beil 13, (140) 2) J. J. Blanksma,
Rec 21, 260 (1902)

\[ \text{[N'}(4-	ext{Ethylaminophenyl}), \text{N'-oxy-N}^\text{3}-\text{methyl-}
\text{N}^\text{3}-\text{phenyl}]\text{triazene or [N}^\text{3}-\text{Methyl-N}^\text{3}-\text{phenyl-
N'-oxy-N}^\prime\text{-4-ethylaminophenyl}]\text{triazene}
\]
Called in Ger: (3-Methyl-3-phenyl-1-4-ethylaminophenyl)-triazenoxyd(1)

\[(\text{C}_2\text{H}_5\text{HN.C}_6\text{H}_4)=\text{N}:\text{N}:\text{N}:\begin{array}{c}
\text{CH}_3 \\
\text{O} \\
\text{C}_4\text{H}_5
\end{array}\]

mw 270.34, N 73%; yel ndls (from alc), mp 97°;
defigr on rapid heating; can be prepd from p-
nitroso-N-ethylaniline hydrochloride [See Beil 7, (345)]
and a-methylphenylhydratetramer in acetic
acid soln, under cooling
Refs: 1) Beil 16, (414) 2) O. Fischer,
(Abstract 1), 908 (1915)

**Ethylaminopolyurethane.** See Aminoethylpoly-
urethane in Vol 1, p A205-R

**Ethylaminopolyvinyl Alcohol and Its Chloride
and Perchlorate.** See under Aminoethylpoly-
vinyl Alcohol in Vol 1, p A205-R

**Ethylaminoprotein.** See Aminoethylprotein in
Vol 1, p A206-L

**Ethylaminopropyleureas.** See Aminoethylpropy-
ureas in Vol 1, p A206-L

**N-Ethylaminotetrazoles.** See AMINOETHYL-
TETRAZOLES and DERIVATIVES in Vol 1, pp A206 & A207 and
5-(Trinitro-N-ethylamino)-tetrazole,
(O$_2$N)$_3$C.CH$_2$-NH-C-\vdash NH-N
\vdash N=N; mw 248.12, N
45.16%, NO$_2$ N 16.94%, OB to CO$_2$ –13%;
cysts, mp 145–46°, explodes at higher temps;
sol in methanol or in 1:1 mixture of nitro-
methane/2-nitroethane

Accdg to description given in ADL Rept
(Ref 3): to the soln of 2g (0.01 mole) amino-
tetrazole hydrate in 20ml warm methanol was
added 2ml (0.027 mole) of 40% formaldehyde
and 3g (0.02 mole) of nitroform and the mixture
refluxed for 3 hours. The resulting red soln
was filtered (to remove any solid)
and filtrate diluted with 40ml of distd w. After
standing for 2 days in an ice chest, the re-
sulting ppt was collected on filter, dissolved
in 20ml methanol and ptd by adding 40ml distd
w. The yield was nearly quantitative
It is a very powerful explosive (about 161.0%
TNT by Trauzl Test)
Refs: 1) Beil, not found 2) R. Stollé & Schiek,
GerP 426343 (1924) 3) R.H. Saunders et al,
Hercules Powd Co Monthly Progress Rept 13
(Sept 1949) (Contract NORD 9925) (Compd
investigated for possible use as a primary expl,
however, its water solubility & thermal stability
were considered unsatisfactory. Its impact
sensitivity with BurMinesApp with 2kg wt was
5cm and the 100°C Vacuum Stability Test value
exceeded the capacity of the app in 48 hrs)
4) ADL, Synthesis HE’s, 2nd Rept (1951), pp
55–6

**N-Ethylaminotoluenes.** See N-Ethyltoluidines
in this Vol

**Ethylaminatriazoles.** See AMINOETHYL-
TRIAZOLES in Vol 1, pp A207 to A209-L

**Ethylaminoureas.** See Aminoethylureas in
Vol 1, p A209

**N-Ethylaminoxylenes or Ethyldimethylanilines.
See N-Ethyloxylenes in this Vol

**Ethylammonium Tetranitrotozinate.**
(EDNH$_3$$\sup{+}{\cdot}$ Zn(NO$_3$)$_4$)$^{2-}$; mw 405.84, N 20.71%
N-Ethylaniline and Derivatives

N-Ethylaniline; N-Phenylenaminoethane or Phenylethylaniline, C₆H₅.NH.C₂H₅; mw 121.18, N 11.56%; colorless liq, turning brown on exposure to light; sp gr 0.963 at 20/4°C, fr p -65.8°C, bp 205.5°C; mp 1.5559 at 20°C; insol in w & petr eth; miscible with alc & eth. It can be prepd by heating aniline with ethanol in presence of sulfuric acid, followed by distillation (Ref 3).

It was used (accdg to Dr H. Walter) during WWII as one of the ingredients of German liquid rocket fuels.

Small quantities of ethylaniline, usually present in Centralites, can be detd by polaro-graphic method described by Sifre (Ref 2).


Note: N-Ethylaniline should not be confused with ortho-, meta- & para-Ethylanilines, C₆H₅.C₂H₄.NH₂, described here under Ethylphenylamines, that are called also Amino-ethylbenzenes.

Nitro-N-ethylanilines, C₆H₄NO₂, mw 166.19, N 16.85%. The following isomers are described in the literature:
2-Nitro-N-ethylaniline, C₂H₅.NH.C₆H₄(NO₂); reddish oil (Ref 1)
3-Nitro-N-ethylaniline, same as above; red-yel ndls, mp 59-60°C (Ref 2)
4-Nitro-N-ethylaniline, same as above, l-yel scales, mp 95-96°C (Refs 3 & 5)
β-Nitroethylaniline, (O₂N)CH₂.CH₂.NH.C₆H₅; 1 flts, mp 37°C (Ref 4).


N-Nitro-N-ethyl-4-nitroaniline, C₂H₅.N(NO₂).C₆H₄(NO₂); mw 211.17, N 19.90%; yel ndls, mp 90°C.

Ref: Beil 12, 729.

Dinitro-N-ethylanilines, C₅H₉N₂O₄; mw 211.17, N 19.90%.

The following isomers are described in the literature:
2,4-Dinitro-N-ethylaniline, C₆H₅.NH.C₆H₄(NO₂)₂; yel or om crysts, mp 114-119°C (Refs 1 & 4)
2,5-Dinitro-N-ethylaniline, same as above, red ndls, mp 120°C (Ref 2)
3,5-Dinitro-N-ethylaniline, same as above, om crysts, mp 185-6°C (Ref 3).


Trinitro-N-ethylanilines, C₆H₃N₃O₆; mw 256.17, N 21.87%; the following isomers are known:
2,4,6-Trinitro-N-ethylaniline or N-Ethyl-2,4,6-trinitroaniline (called Ethylpicramide by van Romburgh), C₆H₅.NH.C₆H₄(NO₂)₃; yel crysts, mp 81.5°C; explodes at higher temps; sf in w; sol in alc & very sol in acet & benz; num-merical values of solubilities in various solvents are given by Desvergnes (Ref 3). It can be prepd from picrylchloride and ethylamine in alcoholic soln (Refs 1 & 2).

It was investigated in Germany during WWII (Ref 4) as a possible substitute for propilns used in mortars. The development never came to a practical realization due to unfavorable raw materials situation.


x,x,x-Trinitro-N-ethylaniline.

C₂H₅.NH.C₆H₄(NO₂)₃; pale-yel ndls (from alc or ethyl acetate), mp 178.5°C. It was prepd by Desvergnes by heating N,N'-diethyl-N,N'-bis (x-trinitrophenyl)-urea in 70% sulfuric acid. It is an explosive.

Refs: 1) Beil 12, (426) 2) L. Desvergnes, RevChimInd 37, 42 (1929)
**N-Ethyl-2,4,6-trinitro-N-nitrosoaniline**, \(C_5H_3N(NO)_2.C_6H_2(NO_3)_3\); mw 285.18, N 24.56%; may be prepared by nitration of the nitrosamine of monoethylaniline with nitric and sulfuric acids. The compound is an explosive.

*Refs:* 1) Beil, not found 2) T. J. Nolan et al., BritP 217614 (1922) & CA 19, 300 (1923)

**N-Ethyl-N,2,4,6-tetranitroaniline; (2,4,6-Trinitrophenyl)nitramino)ethane; N-Ethyl-N-nitro-2,4,6-trinitroaniline**; Ethylpicrylnitramine; called by Blatt 2,4,6-Trinitrophenylnitramine and code named Ethyl Tetryl (Called in Beil: N-Nitro-N-ethyl-2,4,6-trinitroanilin; N-Nitro-N,2,4,6-tetranitroanilin; Ethyl-pikrylnitramin or Tetraethyl; French name Tétréthyl), \(C_8H_8N(NO_3)_2.C_6H_2(NO_3)_3\); mw 301.18, N 23.26%, OB to CO2 - 61.1%; pale yellow, monoclinic prismatic crystals; sp gr 1.644 at 10^° C, mp 95-96°C; explodes at higher temp; insol in w, sol in alc, benz, chl and nitric acid (See Ref 6). It was prepared by van Romburgh (Refs 1 & 2) by treating with nitric acid mono- or di-ethylaniline. Blanksma (Refs 1 & 3) prepared it from N-ethyl-4-nitroaniline by nitration; can also be prepared by nitrating ethylnitramine. It was prepared after WWII in France and its properties determined (Refs 9, 10 & 11).

It is an more powerful than TNT (111% or 115% as deter by Trauzl Test), but more sensitive to impact (FT 92% PA). Its detonation velocity is 62000 m/sec at sp gr 1.10, vs 5000 for TNT at the same sp gr (Refs 7 & 8).

It was proposed as a booster charge in HE shells.


**N-Ethylamine-pentazidecuprate,** \([C_8H_12N][Cu_2(N_3)_3]\); mw 459.37, N 48.79%; mp - explodes with a loud report at 187-89°C; burns with cracking noise and detonates on impact; was prepared from CuCl_2·2H_2O in methanol by adding ethylamine and sodium azide in hot water.

*Refs:* 1) Beil, not found 2) A. Cinulis & M. Straumanis, Ber 76B, 825-30 (1943) & CA 38, 1972 (1944)

**N-Ethyl-N,2,3,4,6-pentanitroaniline,** \(C_8H_8N(NO_3)_2.C_6H_2(NO_3)_3\); mw 346.17, N 24.28%; crystals, mp 96°C; sol in benz & toluene; may be prepared by treating 3,4-dinitro-N,N-diehtylaniline and sodium nitrate in dilute nitric acid and nitrating the resulting product with nitric acid (d 1.49) and sulfuric acid.

*Refs:* 1) Beil 12, 372 2) P. van Romburgh & J.H. Schepers, AkadAmsterdamVersl 22, 299 (1913) & CA 8, 3656 (1914)

**n-, m- and p-Ethylanilines.** See Ethylphenylamines or Aminoethylbenzenes in this Vol (Not to be confused with N-Ethylanilines, also known as Phenylaminoethane)

**Ethylazohexanoate and Derivatives**

**Ethyl-2-azahexanoate,**

**CH_3.CH_2.CH_2.NH.COOC_2H_5.CH_3**; mw 145.20, N 9.65%. It may be considered as the parent compound of its pentanitro deriv although not used to prep it.

**Trinitroethyl-2,5,5-trinitro-2-azahexanoate,**

**CH_3.C(NO_3)_2.CH_2.CH_2.N(NO_3)2.COOC_2H_5.CH_3;** mw 315.20, N 31.11%; solid, mp 107° C, d 1.73; hot bar ignition temp 221°C, sensitivity ~ approx equal to Pentolite. It was prep by nitrating the carbamate from 3,3-dinitrobutyl isocyanate & trinitroethanol.


**Ethylazoauric Acid.** See Vol 1, p A517-R under AZAUROLIC ACIDS

**Ethyl Azelate or Diethyl Azelate and Derivatives**

**Ethyl Azelate,** **(CH_2)_4(COO.C_6H_5)_2;** mw 244.32, liquid, sp gr 0.973 at 20/4°C, bp 291-92°C, insol in w; sol in alc or eth. It can be prep by
esterification of the acid with ethanol catalyzed by H₂SO₄ or HCl gas and with water removal by azeotropic distillation with benz or toluene (Ref 1). Other props in Ref 2

Bis(trinitroethyl)azelate,
\[(O_2N)_3C-CH_2OC(CH_2)_4COCH_2C(NO_2)_3\]; mw 514.36, N 15.97%; OB to CO₂ -59%; liq, fr p -10°; sol in methylene chloride-pentane; impact sensitivity 90cm (for 50% point on BM Machine). It was prep'd by heating slowly at 65° azelaic acid chloride & trinitroethanol over a period of 4 hrs. The reaction mixt was allowed to stand overnight, washed with water and recrystd at low temp from methylene chloride-pentane. This compd may be useful as plasticizers or desensitizers of expls (Ref 3)
Refs: 1) Beil, not found 2) CA, not found 3) D.L. Kouba et al, Hercules Progress Rept on High Explosives (2 Nov 1951)(Navy Contract NOrd 11280, Task A)

Ethyl Azide. See Azidoethane under Ethane and Derivatives, in this Vol, p E142-R

Ethylazidooacetate. See under Ethyl Acetate in this Vol

Ethylazidobenzamide or N-(β-Azido-ethyl)benzamide, C₆H₄.CO.NH.CH₂.CH₃(N₃); mw 190.21, N 29.46%; oil; explodes violently on contact with concd sulfuric acid. It can be prep'd from benzoyl chloride and β-azidoethylamine in the presence of NaOH (Refs 1 & 2)

N-[β-Azidoethyl]-benzamide,
\[C₆H₅.CO.NH.CH₂.CH₃·N₃\]; mw 190.21, N 29.46%; oil which decomposes violently on contact with concd sulfuric acid. It can be prep'd from benzoyl chloride and β-azidoethylamine in the presence of NaOH
Refs: 1) Beil 9, (97) 2) M.O. Forster and S.H. Newman, JCS 99, 1279 (1911)

3-Nitroethylbenzamide, 3NO₂.C₆H₄.CO.NH.C₆H₅; mw 194.18, N 14.42%; mp 143°, bp 310-15°. It may be prep'd from ammonium benzoate by heat-
ing (exploves), 3-Nitrobenzoyl chloride and ammonia, anhydride of 3-Nitrobenzoic and acetic acids and ammonia, 3-Nitrobenzoic bromide and sodium ethoxide, and benzamide and abs nitric acid

4-Nitroethylbenzamide,

4-NO₂-C₆H₅·CO.NH·C₆H₅; mp 151°; sol in alc, in sol in w. It may be prep'd from 4-Nitrobenzoyl chloride and EtNH₂

Refs: 1) Beil 9, [710] 2) H. Wenker, JACS 60, 1081 (1938)

**ETHYLBENZENE AND DERIVATIVES**

*Ethylbenzene or Phenylethane, C₆H₅·C₂H₅; mw 106.16; colorless liq, resembling methylbenzene (toluene), sp gr 0.867 at 20/4°C, nD 1.4959 at 20°, fr p -95.0°C, bp 136.2°, fl p 85°F (29.5°C); sp heat 0.41cal/g, viscosity 0.64 centipoise at 25°; heat of combustion at C₆H₅, 108.9 kcal/mole, heat of vaporization 81.1 cal/g at bp; very st sol in w (0.01% at 15°); v sol in alc, eth, benz & chl; insol in Amm hydroxide. It can be prep'd by heating benzene and ethylene in presence of Al chloride with subsequent distillation, or by fractionation directly from the mixed xylene stream in petroleum refining. Purification is by rectification. It is used in org synthesis, as solvent & diluent and for prep of explosive azidonitro-, dinitro-, trinitro- & higher nitrated derivatives


*Ethylbenzene Azide or Azidoethylbenzene, C₆H₅·C₂H₅·N₃; mw 147.17, N 28.54%. Refs were found only for α- and β-azidophenylethanes. No refs to α-, m- or p-azidophenylethanes were found

1-Azido-1-phenylethane, \( \text{CH}_₃ \)

\( \text{N}_₃\text{C}-\text{H} \)

\( \text{C}_₀\text{H}_₅ \); liq, sp gr 1.0321 at 25/4°C, nD 1.5233 at 25°, bp 114° at 50mm, 83° at 20mm. It may be prep'd by treating 1-chloroethyl benzene with sodium azide in aq methanol


2-Azido-1-phenylethane, N₃C₂H₅·CH₂·C₆H₅; oil, nD 1.5308 at 25°; bp 121-25° at 20mm, 52-4° at 0.65mm. It may be prep'd by treating PhCH₂·C₂H₅·Br with sodium azide or with 1,1,3,3-tetramethylguanidiniumazide (Ref 3)


**Ethylbenzene, Nitro derivatives were patented by the late Dr Hale of PicArsn as colloid ing agents for NC in manuf of smokeless propellants

Ref: G.C. Hale, USP 1964826 (1934) & CA 28, 5242 (1934)

1-Ethyl-mono nitro benzene, C₆H₅·C₂H₅·NO₂; mw 151.16, N 9.27%, OB to CO₂ -195.3%

When ethylbenzene is nitrated, a mixture of ortho- and para-nitrobenzenes in the proportion 2 to 1 is usually obtained. They are suitable as gelatinizers for NC or (or 2-) Nitro-1-ethylbenzene, colorless oil, sp gr 1.126 at 24.5°, fr p -23°, bp 227-28°; insol in w; v sol in alc; sol in eth (Ref 1); QO = 1048.06 kcal/mole and QF = 11.79 kcal/mole (Ref 3)

m-(or 3-) Nitro-1-ethylbenzene, sp gr 1.1345 at 0°, bp 242-43°. It may be prep'd from 4-amino-3-nitroethylbenzene and isoamyl nitrile. (Ref 2)

p-(or 4-) Nitro-1-ethylbenzene, sp gr 1.124 at 25°, fr p -32°, bp 245-46°; insol in w; v sol in alc or ether (Ref 1); QO = 1046.40 kcal/mole and QF = 13.45 kcal/mole (Ref 3)


α-Azido-β-nitroethylbenzene, C₆H₅·CH(N₃)CH·NO₂; mw 191.17, N 29.31%. It may be prep'd from 1-nitro-2-phenylethene and sodium azide in acetic acid. It is violently decomposed in concd sulfuric acid at RT

Refs: 1) Beil, not found 2) J.H. Boyer, JACS 73, 5248-52 (1951) & CA 47, 490 (1953)

4-Nitro(2-nitroethyl)benzene,

NO₂·CH₂·CH₂·C₆H₅·(NO₂); mw 196.16, N 14.28%, solid (from acet ac), mp 163-64°. It may be prep'd from 2-nitro-2-(p-nitrobenzyl)-1,3-indandione and Na in ethanol

1-Ethyl-2,4-dinitrobenzene or 2,4-Dinitro-1-ethylbenzene (DNEtB), C₇H₇C₆H₄(NO₂)₂; mw 196.16, N 14.28%, OB to CO₂ -130.05%; yel oil liq, sp gr 1.3171 at 20°C, nD 1.5655 at 25°C, fr p ?, bp 195.5°C at 33 mm; v sl sol in w; sol in 95% alc 9.34g in 100g at 4°C and 22.70g at 25°C, sol in ether. It is a mild expl which possesses the property of gelatinizing NC; has been used as a flash-reducing agent in smokeless propellants in lieu of DNT (Refs 1-4). Tavenier (Ref 5) gives its Q_c = 514.5 cal/g at 300°C and Q_f = 65 cal/g. It can be prep by a one- or two-stage nitration of ethylbenzene with nearly quantitative yields. Trial nitrations conducted at PicArsn have shown that the mixed acids must be weaker than those used for the nitration of toluene to the dinitro-stage, otherwise excessive oxidation of the ethyl group takes place.

One-stage nitration of commercial ethylbenzene, conducted at PicArsn by Varrato (Ref 2) yielded an oil of fr p betw -12 & -16.5°C, consisting mostly of DNEtB with N content about 14.3%. Although this product was found to be a better gelatinizing agent for NC than DNT, it was not desirable to use it because its N content was lower than that for DNT (N content about 15.4%), which would result in lower potential propellants prep with DNEtB. By pushing the nitration a little further, it was possible to obtain a product with N content approaching that of DNT (N content about 15.4%) and still to have an oil which was a good gelatinizer. This oil contd about 35% of Trinitroethylbenzene, while the rest (65%) consisted of DNEtB and impurities.

When it was desired to prepare propellants with higher potential than those with DNT, nitration went even further, such as to prepare a mixture of N content 16.3%, which contd about 64% of TNEtB and was still oily. Even if nitration of commercial EtB went to completion and the resulting product consisted mostly of TNEtB, it was still nearly liquid at RT (mp ca 21.5°C) and a good gelatinizer for NC. Its N content was 17.25% vs 18.5% for commercial TNT (Ref 2).

Note: Accdg to remark made by Mr H. A. Aaronson (Refs 3 & 4) while he was still working at PicArsn and developed a process for nitration described below, a number of experimental propellants were prep at the Arsenal using DNEtB and its mixts with TNEtB as gelatinizers in lieu of DNT. He does not think that the question of N content is as important as the yields, which are poor for TNEtB and good for DNEtB.

Plant Procedure for Preparation of 2,4-Dinitroethylbenzene
1) 50 lbs of EtB and 130 lbs of "cycle acid" were placed in a standard stainless steel nitratior with coils for heating and cooling and a double-paddle agitator.

Note: "Cycle acid", which is weaker than mixed acid is used for starting the nitration in order not to allow the reaction to become too violent and to be able to more easily control the temp during the early stages of nitration. The compn of the "cycle acid" is similar to that used in the mononitration of toluene, such as H₂SO₄ 53.5, HNO₃ 7.2, Nitoso 15.0 & nitro bodies 10.0%, which was listed by Clift & Fedoroff in "A Manual for Explosives Laboratories", Vol 1, Chap III, p 2 (1942).

2) While maintaining the temperature at 55°C and the agitation at 75RPM, 220 lbs of mixed acid (H₂SO₄ 59.8 & HNO₃ 22.1%) were slowly added. Total time of mononitration was about 1 hour, 15 mins.

3) The mixture was allowed to settle for 6 mins to form a sharp line of separation, and the spent acid (which contd 6-10% nitric acid & 0.5-0.7% nitro bodies and separated at the lower part of the nitratior) was run off, until about 130 lbs of it remained in the nitratior.

4) After this, the agitation was set at 100RPM and the temp raised to about 80°C. Mixed acid (220 lbs) of the same compn as above was slowly added and the nitration continued for 1 hr, 45 mins at 80-83°C.

5) The mass was then cooled to 40°C, allowed to settle for 6 mins and the spent acid (which contd about 7-10% nitric acid and 1.3-1.5% nitro bodies) was run out.

6) The remaining crude DNEtB was washed to neutrality with several changes of water (Ref 4).

2,4-Dinitroethylbenzene, US Specification Requirements and Tests were given in Joint Army-Navy Spec JAN-D-685, 30 Sept, 1948. We are including the Spec here although 2,4-DNEB is not used in current US proplnts as a replacement for DNT.

1. **Appearance.** Clear, amber colored liquid, as determined by visual inspection.

2. **Specific Gravity.** 1.31 ± 0.01 at 15.5°/15.5°, as det by Westphal Balance or by pycnometers (See Vol 3 of Encycl, pp D68 to D71, under Density and Specific Gravity).

3. **Refractive Index.** 1.563 ± 0.001 at 25° can be determined using an Abbé refractometer or other standard apparatus.

4. **Nitrogen Content.** 14.30 ± 0.20%.

**Reagents:**

a) **Standard 0.2N Titanous Chloride Solution** from Titanous Hydride (Method developed by N.M. Liszt of PicArsn is described in Vol 5 under DYNAMITE, GENERAL METHOD OF ANALYSIS APPLICABLE TO COMMERCIAL BLASTING EXPLOSIVES and also in MIL-STD-286B, Dec 1967, Method 601.1.1. This method is recommended. An older method of prep of 0.15N TiCl₃ soln from 20-percent commercial Titanous Chloride soln as described in Vol 1, pp A415-R & A416-L is applicable here, except that 150ml of the 20% soln are mixed with 100ml of 38%HCl and the soln diluted to 1 liter. A detailed description of prep is given under DYNAMITE in Vol 5.

**Standardization of TiCl₃ Solution** is done by potassium dichromate as fully described under DYNAMITE or briefly under Method 601.1.1 in MIL-STD-267B, Dec 1967.

**Standard 0.15N Ferric Ammonium Sulfate Soln** can be prep in the same manner as described in Vol 1, p A415-R for prep of 0.05N soln, but making it three times stronger by using 75g of sulfate for each liter of the reagent. A detailed description is given in Vol 5, under DYNAMITE and also in JAN-D-685.

**Standardization of Ferric Ammonium Sulfate Solution** is done against std 0.2N TiCl₃ soln as described in Vol 5 under DYNAMITE or in JAN-D-685.

**Procedure for Determination of Nitrogen in Dinitroethylenzene.** Transfer an accurately weighed portion of approx 0.5g of the sample to a 250-ml volumetric flask, make up to volume with glacial AcOH and mix thoroughly. Avoid temp changes on acct of the high thermal coeff of AcOH. Displace air in the titration flask (Fig Et14) by passing a current of CO₂ from Kipp generator (fig Et13) into the flask for 5 mins, and continue passing during the following ops. Rinse a calibrated 25-ml pipet with AcOH soln of the sample, and then transfer a 25-ml aliquot portion of the soln to the titration flask. Add an accurately measured portion of 50.00ml of the 0.2N TiCl₃ soln and 25ml of 15% HCl soln. Add few glass beads to the flask (to prevent bumping during boiling) and connect it to reflux condenser. Boil the mixture gently for 20 mins on a hot plate, then increase the current of CO₂ and cautiously immerse the flask with condenser attached in cold w contained in a large beaker. After the flask and contents have cooled to RT, remove the condenser and titrate the contents of the flask with the ferric ammonium sulfate soln. Note the end point (which is indicated by the fading of the color due to titanous chloride), add 5ml of 20% ammonium thiocyanate soln and continue the titration to the first red color which remains for at least 3 mins. Run a blank det in exactly the same manner using exactly 50.00ml of the 0.2N TiCl₃ soln.

**Calculation:**

\[
\text{% Nitrogen} = \frac{0.2335(V - V_1)N}{W}
\]

where:

\[ V = \text{ml of ferric ammonium sulfate soln required for the blank} \]

\[ V_1 = \text{ml of ferric ammonium sulfate soln required to titrate the excess TiCl}_3 \text{ after reduction of DNE BETZ} \]

\[ N = \text{normality of the ferric ammonium sulfate soln} \]

\[ W = \text{grams of sample contd in the aliquot} \]

5. **pH Value of Water-Alcohol Extract, 5.0 to 8.0.** Transfer a weighted portion of approx 30g of the sample to a 500-ml separatory funnel, and add 300ml of a mixture of 250ml diis w & 50ml of 95% ethanol. The mixt having a pH value betw 6.0 to 8.0. Shake the mixt vigorously for 1 min and allow to stand for 15 mins to allow separation into two layers. Determine the pH value of a portion of the upper water-alcohol layer, using a glass electrode.

6. **Benzene-Insoluble Matter, max 0.10%.** Transfer a weighted portion of approx 10g of the sample to a 250-ml beaker, add 150ml benzene and stir.
the mixture until all soluble matter is dissolved. Decant the liquid and filter it thru a tared sintered glass crucible. Transfer any insoluble matter from the beaker to the crucible by means of a stream of benzene and rinse with addnl 10ml of benz. Suck air thru the crucible until only a slight odor of benz could be detected. Heat in an oven for 30 mins at 100-105°, cool in a desiccator and weigh

\[
\% \text{ Insolubles} = \frac{Wt \text{ of insol} \times 100}{Wt \text{ of sample (10g)}} \%
\]

7. **Loss on Vacuum Desiccation**, max 0.25%. Transfer a portion of approx 2g of the sample to a tared moisture denm dish, approx 2 inches in diam and reweigh the dish with the sample. Place it in a vacuum desiccator over concd sulfuric acid (95 to 97% strong) for 24 hours and then reweigh the ensemble

\[
\% \text{ Loss} = \frac{\text{Loss of wt} \times 100}{Wt \text{ of sample}} \%
\]

**1-Ethyl-dinitrobenzenes, C₆H₅-C₆H₄(NO₂)₂;** Beilstein lists the following Dinitroethylbenzenes:

**FIG 14 – TITRATION FLASK**

- **1-Ethyl-2,4,6-trinitrobenzene or 2,4,6-Trinitro-1-ethylbenzene (TNEtB);** listed in some papers as 2-Ethyl-1,3,5-trinitrobenzene, C₆H₅-C₆H₄(NO₂)₃; mw 241.16, N 17.43%, OB to CO₂ –89.6%; nearly colorless crysts, mp 37°; nearly insol in w; sl sol in alc; sol in
ether, benz and other org solvents in which TNT is sol; forms a eutectic with about 31% TNT, melting at about 2°; like TNT, it is colored red in presence of caustics. For its laboratory prep, add slowly, with stirring, 1 part of 2,4-DNEtB to 7.25 parts of mixed acid consisting of about 22.2% nitric acid & 72.2% sulfuric acid, maintained at 75° in a stainless steel beaker, provided with an agitator and placed in a water bath. Maintain the agitation at 75° for 6 hours, disconnect the agitator, remove the beaker from water bath and allow to stand in the air until the oil (crude TNEtB) separates in the upper layer. Decant the oil into the 2nd stainless beaker, leaving the "spent acid" in the 1st beaker. Fortify the acid with nitric acid to the strength of "cycle acid", listed under prep of 2,4-DNEtB for purification of crude TNEtB in the 1st beaker, add hot water and agitate for a few minutes. After decanting the acidic water, agitate with a hot water Na carbonate soln, followed by 2–3 washings with hot water, under agitation. After this, the mass is grained in the following manner:

Transfer the hot oil into a flat porcelain casseole, place it on a piece of insulating material (wood, cardboard, asbestos) and stir the oil by means of a strong glass rod with a flattened end. Stir quickly with a rotary motion, occasionally pushing the crust formed at the edges back into the liquid. As soon as the oil starts to fudge, watch for lumps and break them as soon as they form with the flattened end of the above glass rod. Keep the bottom of the casseole clear of crust and continue to break the lumps. Finally the mass assumes a silky crystalline appearance and breaks into powder, which is crude TNEtB. The yield is only 75%, but it is still poorer (only 70%), if one-step nitration of EtB is used.

If higher purity of the material is desired, transfer the particles of TNEtB into a Büchner funnel (Nutsch) and wash them first with small amount of alcohol, then with ether. After removing the rinsings by suction, dry crystals by air.

TNEtB is an explosive, similar in its properties to TNT, but slightly less powerful and brisant. As it is more expensive to prep than TNT, it had no practical application in explosions industry or for military purposes.

Refs: 1) Beil 5, 360 2) P. Varrato, PATR


1-Nitro-4-(2,2,2-trinitroethyl)-benzene,
\[
\begin{align*}
&\text{NO}_2 \\
&\text{HC} \equiv \text{C} = \text{CH} \\
&\text{HC} \equiv \text{C} = \text{CH}_2 \cdot \text{C} = \text{C} = \text{NO}_2 \end{align*}
\]

\[
\text{CH}_2 \cdot \text{C} = \text{C} = \text{NO}_2 \text{; mw 286.16, N 19.58% ; crysts (from alc + CCl}_4 \text{; mp 135°. It may be prep from p-nitrobenzyl bromide and silver nitroform (from silver oxide and nitroform) in ether for 50 h. It is a powerful explosive)}
\]


1,3,5-Trinitro-4-(2,2,2-trinitroethyl)-benzene,
\[
\begin{align*}
&\text{NO}_2 \\
&\text{HC} \equiv \text{C} = \text{CH} \\
&\text{O}_2 \text{N}, \text{HC} \equiv \text{C} = \text{C} = \text{NO}_2 \end{align*}
\]

\[
\text{CH}_2 \cdot \text{C} = \text{C} = \text{NO}_2 \text{; mw 376.15, N 22.34% ; crysts (from ethyl nitrate + CHCl}_3 \text{; mp 153–4°. It may be prep from 2,4,6-trinitrobenzyl bromide and silver nitroform (from silver oxide and nitroform) in ether for 18 h. It is a powerful explosive)}
\]


3,5-Bis(2,2,2-trinitroethyl)-1-nitrobenzene,
\[
\begin{align*}
&\text{NO}_2 \\
&\text{HC} \equiv \text{C} = \text{CH} \\
&\text{C} = \text{CH} \equiv \text{C} = \text{CH}_2 \cdot \text{C} = \text{C} = \text{NO}_2 \text{; mw 449.22, N 21.83% ; crysts (from CHCl}_3 \text{; mp 170–171.5° (slt decompm); it may be prep from 3,5-bis(bromomethyl)-1-nitrobenzene and silver nitroform in ether for 3 days. It is a powerful explosive)}
\]

Refs: 1) Beil 5, 968 2) W.S. Reich, G.G. Rose & W. Wilson, JCS, 1234–7 (1947)
1,3,5-Tris(2,2,2-trinitroethyl)benzene,
\[ \text{CH}_2\text{C(NO}_2\text{)}_3 \]

H\[C\text{==CH} \]
C\[==\text{C.H}_2\text{C}(\text{NO}_2)\_3 \]
H\[C\text{==C(NO}_2\text{)}_3 \]

mw 567.26, N 22.22%; crystals (from CHCl\(_3\)), mp 205–06° (decomp). It may be prepd from 1,3,5-tris-(iodomethyl)benzene and silver nitroform (from silver oxide and nitroform) in ether. It is a powerful explosive


**Ethylbenzene Sulfonamide and Derivatives**

**Ethylbenzene Sulfonamide** (called Benzolsulfo-säureäthylamid in Ger),
C\(_6\)H\(_5\)SO\(_2\)NH.CH\(_2\).CH\(_3\); mw 185.25, N 7.6%; crystals (from alc), mp 57–58°. It can be prepd from benzencesulfolchloride & ethylamine in water

Ref: Beil 11, 40

**Dinitroethylbenzene Sulfonamide**, C\(_6\)H\(_3\)N\(_2\)O\(_4\)S, not found in the literature thru 1966

**N-Trinitroethylbenzene Sulfonamide**,
C\(_6\)H\(_5\)SO\(_2\)NH.CH\(_2\).C(NO\(_2\))\(_3\); mw 320.24, N 17.50%; crystals, mp 172°, d 1.64, ignition temp 188°, sensitivity approaches that of Comp B. It is prepd by fusing the sulfonamide with an excess of Trinitroethanol at 100°


**N-Trinitroethyl-nitrobenzene Sulfonamide**,
C\(_8\)H\(_7\)N\(_2\)O\(_4\)S, mw 365.25, N 19.18%. Two isomers are known:

**N-Trinitroethyl-m-nitrobenzene Sulfonamide**, m-O\(_2\)N.C\(_6\)H\(_4\).SO\(_2\)NH.CH\(_2\).C(NO\(_2\))\(_3\); crystals, mp 149°, d 1.70, ignition temp 198°, sensitivity approaches that of TNT; prepd by fusing the sulfonamide with twice the theoretical quantity of Trinitroethanol at 90°(Refs 2 & 3). It is a powerful explosive

**N-Trinitroethyl-p-nitrobenzene Sulfonamide**, p-O\(_2\)N.C\(_6\)H\(_4\).SO\(_2\)NH.CH\(_2\).C(NO\(_2\))\(_3\); crystals, d 1.79, ignition temp 206°; sensitivity — about the same as Comp B. It is prepd by fusing the sulfonamide with twice the theoretical quantity of Trinitroethanol at 70°(Refs 1 & 3). It is a powerful explosive


**Ethylbenzoate and Derivatives**

**Ethylbenzoate** (Called in Ref 2, Benzoic Ether),
C\(_6\)H\(_5\).CO\(_2\).C\(_2\)H\(_5\); mw 150.17; colorless aromatic liq, sp gr 1.052 at 15/15°, n\(_D\) 1.505 at RT, fr p -34.7°(-32.7°), bp 212.4°(212.9°); insol in cold w, sl sol in hot w; miscible with alc, eth, chl & petr ether. It can be prepd by heating ethanol with benzoic acid in the presence of sulfuric acid. It is used as flavoring extract and as a solvent for many cellulose derivatives and for resins


**Ethyl nitrobenzoates**, O\(_2\)N.C\(_6\)H\(_5\).CO\(_2\).C\(_2\)H\(_5\); mw 195.17, N 7.18%

**Ethyl-2-nitrobenzoate**, triclinic crystals, mp 30°, bp 173° at 18mm. It may be prepd from 2-nitrobenzoic acid with alcohol and K pyrosulfate and from o-nitrobenzaldehyde in alcohol

Ref: Beil 9, 372 & (151)

**Ethyl-3-nitrobenzoate**, monoclinic prisms, mp 47°, bp 296°. It may be prepd by saturating an alc soln of the acid with HCl gas; from the acid salt of 3-nitrobenziminoethylether; from the 3-nitro acid and diazoethane and from the 3-nitrobenz in boiling abs alc and HCl gas

Ref: Beil 9, 378, (151), (154) & [248]

**Ethyl-4-nitrobenzoate**, phtals (from alc), mp 57°. It may be prepd from the acid in alc in the presence of HCl, from the methyl ester and excess alc in the presence of KO\(_2\)H

Ref: Beil 9, 390 & [258]

**Ethyl dinitrobenzoates**, (O\(_2\)N\(_2\))\(_2\).C\(_6\)H\(_5\).CO\(_2\).C\(_2\)H\(_5\); mw 240.16, N 11.66%

**Ethyl-2,3-dinitrobenzoate**, mp 88.4°. It may be prepd from the acid and the alcohol in the presence of hydrochloric acid

Ref: Beil 9, 411

**Ethyl-2,4-dinitrobenzoate**, ndls (from alc), mp 41°. It may be prepd from the acid in alcohol in the presence of HCl gas, from the silver salt of the acid and ethyl iodide
Ref: Beil 9, 412
Ethyl-2,5-dinitrobenzoate, crs (to alc), mp 60.5-70°. It may be prepd from the acid and alcohol with hydrochloric acid
Ref: Beil 9, 412
Ethyl-2,6-dinitrobenzoate, crs (to alc), mp 74.7°. It may be prepd from the silver salt of the acid and ethyl iodide
Ref: Beil 9, 413
Ethyl-3,4-dinitrobenzoate, mp 71°. It may be prepd from the acid and alcohol with HCl gas from the acid chloride and ethanol
Ref: Beil 9, 413, [1779]
Ethyl-3,5-dinitrobenzoate, nds (to alc), sp gr 1.295 at 111°, mp 91-92°, bp - not given; insol in w; sl sol in alc. It may be prepd from the silver salt of the acid and ethyl iodide, from the acid and alc HCl; from the acid chloride in benzene; from the chloride and ether with zinc chloride
Ref: Beil 9, 414, [280] & [1781]

2,2,2-Trinitroethyl benzoate
C<sub>6</sub>H<sub>4</sub>CO<sub>2</sub>CH<sub>2</sub>C(NO<sub>2</sub>)<sub>3</sub>, mw 285.17, N 14.74%, mp 72°, sensitivity about that of TNT. It may be prepd by heating benzamide and an eq mt of nitroform, formaldehyde and nitric acid to 50°. Trinitroethanol may be used instead of nitroform and formaldehyde. It is an explosive
Refs: 1) Beil, not found 2) W.F. Sager & D.V. Sickman, NAVORD Rept 483(1952)
3) R. Schenck, SwedP 138456 (1952) & CA 48, 2759 (1954)

2,2,2-Trinitroethyl-m-nitrobenzoate,
m-O<sub>2</sub>N.C<sub>6</sub>H<sub>4</sub>COO.CH<sub>2</sub>C(NO<sub>2</sub>)<sub>3</sub>, mw 330.17, N 16.97%, crystals, mp 97°, sensitivity - about that of Comp B. It was prepd by nitration of Trinitrobenzyl. It is an explosive
Refs: 1) R.H. Saunders et al, Hercules.PowdCo Progress Rept (Sept 1948) (Contract NOrd 9925)
2) W.F. Sager & D.V. Sickman, NAVORD Rept 483(1952) (Res & Develop in New Chem HE’s)

2,2,2-Trinitroethyl-3,5-dinitrobenzoate,
(O<sub>2</sub>N)2C<sub>6</sub>H<sub>4</sub>COO.CH<sub>2</sub>C(NO<sub>2</sub>)<sub>3</sub>, mw 375.17, N 18.67%, crystals, mp 138°, d 1.67, ignition temp 305°, sensitivity - about that of Comp A; prepd by treating the acid chloride & Trinitromethanol with anhyd AlCl<sub>3</sub>. This compd is a good expl, but of low density
Refs: 1) M. Hill, NAVORD Rept 2245 (1951)
2) W.F. Sager & D.V. Sickman, NAVORD Repr 483(1952)

2,2,2-Trinitroethyl-2,4,6-trinitrobenzoate,
(O<sub>2</sub>N)3C<sub>6</sub>H<sub>2</sub>COO.CH<sub>2</sub>C(NO<sub>2</sub>)<sub>3</sub>, mw 426.16, N 19.72%, crystals, mp 133-35°, d 1.80, 5 sec ignit temp 240°, hot bar ignit temp 284°, Blm impact sensitivity 43cm. It was prepd from reaction of Trinitromethanol and the acid chloride in Nitrobenzene soln, or from the alcohol & acid in oleum. It is a powerful explosive
Refs: 1) Beil, not found 2) D.V. Sickman & W.F. Sager, NAVORD Rept 486 (1954)

Ethylbenzol. See Ethylbenzene

Ethyl-o-benzoylbenzoate or Ethylester of Benzoylbenzoic Acid(Aoxo-diphenylmethanocarbonsäure-2-äthyester or Benzoylbenzo-säure-2-äthyester, in Ger),
C<sub>6</sub>H<sub>4</sub>CO.C<sub>6</sub>H<sub>4</sub>COO.CH<sub>3</sub>; mw 254.27, rhombic plates, sp gr 1.221 at 64.5°/4°, mp 1.560 at 64.5°, mp 58°; insol in w; v sol in alc or eth. It can be prepd by treating 2-benzoylbenzoic acid with ethanol and sulfuric acid (Ref 1). Goodyear (Ref 2) proposed its use in the prep of progresive burning double-base smokeless propmts. For this the grains of propellant are coated at temp below 50° with an admixure of ethyl-o-benzoylbenzoate (which is a solvent for NC), rosin, and a nonvpl, nonvpl or org compd, such as butylacetyl ricinoleate.
Refs: 1) Beil 10, 749, (356) & [517] 2) E.S. Goodyear, USP 2179330 (1940) & CA 34, 1488 (1940)

Ethyl-s-Nitro-o-benzoylbenzoate,
C<sub>6</sub>H<sub>4</sub>CO.C<sub>6</sub>H<sub>3</sub>(NO<sub>2</sub>).COOC<sub>2</sub>H<sub>5</sub>; mw 299.29, N 4.68%, mp 86°. This ester was prepd by reacting diphenyl cadmium and 4-nitrophthalic anhydride to give the acid which was esterified


Ethylbenzylamine Chlorate. See Benzylethylamine Chlorate under CHLORATES in Vol 2 of Encycl, p C187-L
Ethyl-bis(aminomethyl)-carbamate and Derivatives

**Ethyl-bis(aminomethyl)-carbamate**, 
\[ \text{H}_2\text{N}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{N}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{NH}_2 \]
\[ \text{CO}_2\cdot\text{C}_2\text{H}_5 \]

It may be considered as a parent cmpd of di-nitrocomp described below, although it was not used for its prep.

**Ethyl-N,N-bis(β-nitraminomethyl)-carbamate**, 
\[ (\text{O}_2\text{N})\text{HN}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{N}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{NH}(\text{NO}_2) \]
\[ \text{CO}_2\cdot\text{C}_2\text{H}_5 \]

mw 265.23, N 28.41%; solid (from 95% alc), mp 104-105°C; heated in a test tube, it melts and decomposes with sudden puff of fumes; when dropped on a hot plate, it burns with yel flame. It was prep'd by ammonolysis of sym-Dinitrodienylenetriethane, 
\[ \text{O}_2\text{N}\cdot\text{N}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{N}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{N}\cdot\text{NO}_2 \]
\[ \text{CO}_2\cdot\text{C}_2\text{H}_5 \]
\[ \text{CO}_2\cdot\text{C}_2\text{H}_4 \]
\[ \text{CO}_2\cdot\text{C}_2\text{H}_4 \]

**Refs:** 1) Beil, not found 2) J.R. Johnson, OSRD 915, 8-9, 12 & 26-27 (1942), pp 8-9

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Ethyl-bis(triazomalonate) or Diethyl diazidomalonate (Called Diethyl diazidomalonsäure-diesthylester in Ger), \( (\text{N}_3)_2\text{(COO.C}_2\text{H}_4)_2 \)

mw 230.18, N 36.51%; pleasant smelling liquid, sp gr 1.236 at 20°C; fr p ?, bp 115-115.5°C at 0.81mm pressure; explodes at 180°C. It can be prep'd by treating diethylchloromalonate, \( \text{Cl}_2\text{(COO.C}_2\text{H}_4)_2 \)
with NaN₃ in dil alc 

**Refs:** 1) Beil, 2, (259) 2) M.O. Forster & R. Müller, ProcChemSoc 26, 4(1910); JChemSoc 97, 136(1910) & CA 4, 1606(1910)

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**Ethyl Borate.** See Vol 2 of Encyl, p B247-L, under Borates

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**Ethyl-t-butyl Peroxide**, \( \text{C}_2\text{H}_5\cdot\text{OO}-\text{C(CH}_3)_3 \)

mw 118.17, O 27.08%; liquid, fr p -83°C, bp 35°C at 84mm, nd₂0 1.3840, d₄0 0.089. It can be prep'd by shaking diethylsulfate for 2 hrs with potassium t-butylperoxide

**Refs:** 1) Beil, not found 2) F.F. Rust et al, JACS 72, 338 (1950) & CA 45, 1010(1951) 3) Tobolsky & Mesrobian (1954), 164

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**Ethylbutyrate and Derivatives**

**N-Ethylbutyramine**, 
\[ \text{H}_3\text{C}·\text{CH}_2·\text{NH}·\text{CO.CH}_2·\text{CH}_2·\text{CH}_3; \text{mw} 115.17, \text{N} 12.16%; \text{liq, bp 101-2° at 7mm}, \text{nd} 1.4372 \text{at 20°}, \text{d 0.9028 (20°)}. \text{It may be prep'd from butyric acid and ethylamine by treatment with SiCl}_4 \text{ in benzene} \]


**N-(2,2,2-Trinitroethyl)-4,4,4-trinitrobutyramide**, 
\[ (\text{NO}_2)_3\text{C.CH}_2·\text{NH}·\text{CO.CH}_2·\text{CH}_2·\text{C(NO}_2)_3 \]

mw 385.17, N 25.45%; colorless crys, mp 149-51°C(decomp); explosive and propellant. It may be prep'd by treating acrylamide with a molar equiv of HCHO to form N-methylolacrylamide on treating with 2 mols nitroform; or, acrylamide and nitroform give 4,4,4-trinitrobutyramide, which treated with formaldehyde and a second mole of nitroform gives the product

**Refs:** 1) Beil, not found 2) US Rubber Co., Reports No 6 and Summary Report, on Contract NOrd 10129(1948) 3) I.J. Schaffner, USP 3038009 (1962) & CA 57, 12330(1962)

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**Ethylbutyrate and Derivatives**

**Ethyl-n-butyrate or Ethyl Butanoate**, 
\[ \text{C}_2\text{H}_5\cdot\text{CO}_2·\text{C}_2\text{H}_5; \text{mw} 116.16; \text{colorless, non-toxic, pineapple smelling liquid; sp gr 0.874 at 25°/4}, \text{fr p -100.8°(-93.3° in Ref 2), bp 121.6°(120.6° in Ref 2), nd} 1.400 \text{at 20°}; \text{nearly insol in w; sol in alc or eth}. \text{It can be prep'd by heating ethanol with butyric acid in presence of sulfuric acid, followed by distillation. It is used in flavoring extracts and in solvent mixtures for cellulose esters & ethers and for many resins}\]


**Ethyl-4,4,4-trinitrobutyrate (EtTNBu)**, 
\[ (\text{O}_2\text{N})_3\text{C.CH}_2·\text{NH}·\text{CO}_2·\text{C}_2\text{H}_5; \text{mw} 251.16, \text{N} 16.73%; \text{liq, fr p 13.4°}, \text{bp 105-06° at 2mm or 81-90° at 0.1mm}, \text{nd} 1.4537 \text{at 25° can be prep'd by refluxing for 5 hours ethylacrylate, CH}_2·\text{CH.CO}_2·\text{C}_2\text{H}_5 and nitroform, (NO}_2)_3\text{CH, in absolute alcohol; the potassium salt of nitroform may also be used} \]

**Refs:** 1) Beil, not found 2) US Rubber Co., Reports No 7 & N0 8 (1949) 3) K. Schimmel-schmidt, GerP 852684 (1952) & CA 52, 10144 (1958) 4) J. Ville, MP 42, 25(1960)
2,2,2-Trinitroethyl-4,4,4-trinitrobutyrate (TNEtTNBu or TNETNB),
\[ (\text{O}_2\text{N})_3\text{C}_2\text{H}_5\text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_3, \text{ mw 386.15, N } 21.76\%; \text{ OB to CO}_2 -4.1\%; \text{ crysts (three polymorphs), sp gr 1.78, mp 93-4\°}; \]
ignition temp 225\°; v sl sol in w; sl sol in alc.; sol in eth; very resistant to hydrolysis and attack by dilute alkalies; it reacts with paraffin and waxes at elevated temps, which might interfere with its desensitization.

It can be prep'd either by interaction of nitroform with trinitroethy lacrylate or by the esterification of trinitroethanol with trinitrobutylchloride in presence of an anhydrous metal chloride (such as AlCl3) as a catalyst; US Rubber Co prep'd it by treating a mixture of trinitroethanol and trinitrobutyric acid with oleum (Ref 7).

TNEtTNBu is an expl, too sensitive to impact for use as HE (16-20cm with 2kg weight); fairly stable in storage at 65\° (loses 0.1-0.3% wt per year); vacuum stability at 100\° - lost 0.6ml in 48 hrs.

No information at our disposal for its brisance and power, but accdg to investigation conducted at Hercules Powder Co Laboratory (Ref 2), mixts TNEtTNBu with AI powder yielded about 30% more shockwave energy and 80-90% more bubble energy than did HBX-1 (RDX 40, TNT 38, Al 17, D-2 Wax 5 and Ca chloride 0.5 added).


**Trinitroethyl-trinitrobutyrate Homologs.** Due to the fact that TNEtTNBu is too sensitive to impact (16-20cm with 2kg wt) for use as a booster or burster charge, attempts were made to desensitize it with substances like paraffin or waxes. It was found, however, that these substances are decmpd at elevated temps by TNEtTNBu. Since it was felt that expls in which one or two NO2 groups are replaced by CH2 might prove (being less sensitive than the original compd) suitable for the purposes indicated above. For this reason, several homologs were prep'd at Laboratories of Hercules Powder Co and of Naval Ord at White Oak, Silver Spring, Md. The first homologs prep'd for the US Navy were Dinitropropyl-trinitrobutyrate and 2,2,2-Trinitroethyl-4,4-dinitropentanate. As the characteristics of these compds seemed to be favorable (notwithstanding their lack of oxygen), several other homologs were prep'd for the Navy. Prepn and props of these homologs were described in confidential reports (declassified by now), listed below as refs:


**Ethylcarbamate or Urathene.** See Carbamic Acid Ethyl Ester in Vol 2, pp C40-R & C41-L

The following derivatives are not described there:

*Ethylcarbamate Azide* (Äthylcarbamidsäure-azid in Ger), C2H5·NH·CO·N3; mw 114.11, N 49.10%; prisms, mp 10-14\°, bp 90° at 28mm. It may be
prep'd from ammonia and ethyl isocyanate in ether
Refs: 1) Beil 4, (354) 2) N. Oliveri-Mandalà,
Gazz.Chimital 43, 309 (1913)
_Nitroethylcarbamate_, O₂N.NH.CO₂.C₂H₅; mw
134.09, N 20.89%; tablets (from eth + petr eth),
mp 64°; sol in water, alc, eth. It may be prep'd
from ethyl nitrate and urethane in concd sulfuric
acid
Ref: Beil 3, 125

_Trinitroethylecarbamate_, H₂N.CO.O.CH₂.C(NO₃)₂;
mw 224.09, N 25.00%; crysts, mp 94°, d 1.79,
ignition temp 214°, sensitivity ~ about the same
as Pentalite. This comp'd is relatively stable
at 90°, but much less stable at 100° in liq.
state. It is prep'd from carbamyl chloride &
Trinitroethanol
Refs: 1) D.L. Koubi & R.H. Saunders, Her-
culesPowdCo Progress Rept (May 1950)
(Contract NoD 9925) 2) W.F. Sager & D.V.
Sickman, NAVORD Rept 483 (1952)

2,2,2-Trinitroethylcarbamic Acid, 2,2,2-
trinitroethylester,
(NO₃)₃C.CH₂HN.CO₂.CH₂C(NO₃)₃; mw 387.14,
N 25.30%; mp 192°. It may be prep'd from tri-
nitroethanol, nitric acid and urea in 92-5% yield
in presence of 10% water; 75% yield with
40% water; HCN(NO₃)₃ + HCHO may be substd
for (NO₃)₃C.CH₂OH. It is an explosive
Refs: 1) Beil, not found 2) R. Schenck,
SwedP 138456 (1952) & CA 48, 2759 (1954)

9-Ethynitrocarbazoles, O₂N.C₆H₄.H₂C₂H₅; mw
241.26, N 11.61%
9-Ethyl-2-nitrocarbazole, crysts, mp 148.5-149°.
It may be prep'd by treating 2-nitrocarbazole in
acetone with aq KOH (66%) and followed by
ethyl chloride
Ref: E. Sawicki, JACS 75, 4106-7 (1953) &
CA 49, 9243 (1955)
9-Ethyl-3-nitrocarbazole, yel crysts (from alc),
mp 128°. It may be prep'd from ethyl carbazole,
NaNO₂ and HCl in boiling benz or with 43% HNO₃
at 10-20°; from 3-nitrocarbazole and Ethyl
bromide or iodide followed by diethylsulfate
in alkali; from ethylcarbazole and tetranitro-
methane in ac ac and CH₂Cl₂, irradiation with
ultraviolet light cuts reaction time from 4 wks
90 mins
Refs: 1) Beil 20, 440, (168) & [288] 2) D.H.
Iles & A. Ledwith, JCS (1969), 364-5 & CA 70,
114937 (1969)

9-Ethyl-1,3,6,8-tetranitrocarbazole,
(NO₃)₄.C₆H₄.N.C₂H₅; mw 375.26, N 18.67%;
dimorphic yel ndls, mp 203°, 216°; sol in acetone.
It may be prep'd from 3,3',5,5'-tetranitro-2,2'-
dimethoxybiphenyl in alcohol and ethylamine
by heating 5 hrs at 100°. It is an explosive
Refs: 1) Beil, not found 2) I.J. van Alphen,
RecTranChim 51, 179-84 (1932) & CA 26,
1273 (1932)

Ethylcarbazole and Derivatives
_Ethylcarbazole,_

mw 195.25, Hts (from eth), mp 67-70°, bp
175° at 5mm; insol in w; sol in eth & hot alc.
It can be prep'd by action of ethyl chloride on
K carbazole. Since its props are similar to
Carbazole, described in Vol 2, p C45, it might
be suitable for use as a stabilizer
Ref: 1) Beil 20, 436, (164) & [282] 2) Cond-
ChemDict (1961), 462-R

_Ethyl- or Diethylcarbonyl, (C₂H₅O)₂CO;
Ethylation or Derivatives_
Hexanitroethylcarbionate, \( \left[ \left(O_2N \right)_3C.CH_2O \right]_2CO \); mw 388.13, N 21.65%; crysts, mp 115°, d 1.88, sensitivity approx that of Pentolite. It is prepd by reaction of phosgene with Trinitroethanol in the presence of \( \text{AlCl}_3 \). This expl has a high oxygen content (62%), high crystal density and excellent stability.


Ethylcelluloses (EtCell) are esters of cellulose in which one or more (up to three) hydroxyl groups are replaced by ethoxy groups \((-OC_2H_5)\). The monoethylcellulose, \( C_6H_12O_7(OH)\frac{1}{2}(OC_2H_5)\frac{1}{2} \), contains 23.68% of \((OC_2H_5)\); the dit-, \( C_6H_{12}O_7(OH)(OC_2H_5)\frac{1}{2} \), contains 41.28% (mp about 150°) and the trit-, \( C_6H_{12}O_7(OC_2H_5)\frac{3}{2} \), contains 54.88% of \((OC_2H_5)\) (mp 240–245°).

The completely substituted product is a white, granular, solid with mw 246.30 and mp 240–45°. Its method of prepn was described by Hess & Müller (Ref 1). The triethylcellulose is insol in w and practically insol in methanol, ethanol & acetone, but sol in clh, pyridine, ethylene dichloride, ethyl acetate, carbon tetrachloride and many other organic solvents. This product has, however, no military or commercial application because it lacks strength & flexibility, is not thermoplastic and shows only very limited compatibility.

A product which contains about 2.5 ethoxy groups (47–48%) is thermoplastic and is suitable for commercial and military uses; its sp gr is 1.07–1.18, nD 1.47 and softening point 240–45°. It can be prepd in a laboratory, by slowly adding (with stirring) to the pulped filter paper (suspended in 44%aq NaOH soln maintained at 100°) an excess of ethyl chloride (usually 6 moles per one mole of cellulose) and allowing to stand for a while.

Note: In order to obviate to some extent the side reactions of hydrolysis, the procedure is conducted in the presence of large amount of NaCl.

The resulting slurry is filtered thru a Gooch and the pulp sucked fairly dry. If analysis will show that the ethoxy content is lower than desired, the treatment with ethyl chloride can be repeated (Ref 3). Technical methods of prepn are described by Dorcé (Ref 4).

R.F. Warren, Edit, gave in Ref 5 a rather detailed description of manuf of military grade EtCell as was conducted after WWII in the USA. The description, which is accompanied by schematic diagram, is not included here since it is described in the literature.

Five types of commercial EtCell were manufd during WWII by the Hercules Powder Co (Ref 2), of which the N-Type, having 46.8 to 48.5% ethoxy content, had sp gr 1.14, mp 200–210° and the same requirements as were listed in US Army Specification No 97–54–176, now replaced by Spec MIL-E-10853B. The product is more resistant to alkali solns than to the acids. Its flammability is of as low an order as any other cellulose derivatives (Ref 2).

Uses of EtCell include: films, adhesives, flexible lacquers, varnishes, plastics, electrical insulators, moulding powders, jelled expls such as used in Bangalore Torpedo (See Vol 2, pp B16 ff), inhibitor tape for rockets and proximity fuzes (Refs 8 & 10).

Most renowned of EtCell uses is the proximity fuze developed during WWII. Out of many plastic materials tested, EtCell was chosen because of its toughness, close-tolerance moulding and heat resistance. All this in spite of the fact that it is a thermoplastic material. (See also Refs 9, 11 & 12).


This spec covers one grade of EtCell but two classes: Class 1 is of high viscosity, while Class 2 is of low viscosity. Class 1 material shall fuse without charring and be capable of being drawn into a thread at a temperature not lower than 145°C, when tested as specified in opn 8.

The EtCell shall be white, porous granules of freshly prep'd stock, manu'd from purified cellulose.

Each lot shall consist of EtCell produced by one manufacturer in not more than 24 consecuitive hours under essentially the same manuf conditions and with no change in materials, provided the operation is continuous. In the event that the process is a batch operation, each batch shall constitute a lot.

A batch is defined as that quantity of material which has been manuf'd by some unit chem process and subjected to some physical mixing opn intended to make the final product substantially uniform.

The EtCell covered by this Spec is intended for use in the manuf of certain munition components (which are not named in the Spec but were named above).

Sampling for examination shall be conducted in accordance with Standard MIL-STD-105. A sample shall be taken from each lot, the size to be calc'd on the basis of one-tenth of the square root of the number of containers in the lot, raised to the next highest whole number. If there are fewer than 3 containers in a lot, each container shall be sampled. In all other cases, no fewer than 3 containers shall be selected. From each container in the sample a representative one pound specimen shall be taken and placed in separate, clean, dry containers which are labeled to identify the lot and container represented. Equal portions of each specimen selected, as described above, shall be thoroughly mixed to form a composite specimen, and this shall be subjected to the tests described below.

Specification Requirements and Tests
1. Ash Content - 0.40% max for Class 1 and 0.10% for Class 2.

Transfer approx 5g of the specimen, weighed to the nearest mg, to a tared porcelain crucible and ignite for 4 hrs in a muffle furnace maintained at 900±25°C, cool in a desiccator and weigh to the nearest mg.

\[
\text{% Ash} = \frac{100A}{W}
\]

where:

\[
A = \text{wt of residue after ignition of specimen, in g}
\]

\[
W = \text{wt of specimen in g}
\]

2. Ethoxy Content - 46.8 to 48.5% for Class 1 and 47.1 to 48.1 for Class 2.

Prepare on the day of test a soln of bromine-Na acetate-acetic acid soln by adding 10ml of bromine to 145ml of 10% soln of anhydrous Na acetate in glacial AcOH.

Procedure: Assemble the apparatus (Fig Et 15) for the ethoxy detn. Grind approx 1 g of the specimen to pass thru 149 micron (No 100) sieve conforming to Spec RR-S-366 and dry it at 100±5° for 2 hrs. Fill the trap T by pouring a small amount of aq suspension of red phosphorus thru the cup C above. Follow with a water rinse, using sufficient liq to make the trap about half full. Weigh to the nearest 0.1mg, appr 50mg of dried sample placed in a tared gelatin capsule. Transfer the capsule to the boiling flask, add a few glass beads and 6ml of constant boiling 57% hydric acid, but do not start heating the flask yet. Place 10ml of bromine-Na acetate-acetic acid soln in the 1st receiver and 6ml in the 2nd one. Place the 2nd receiver with contents under the side arm of the 1st receiver until the side arm is approx 0.5 inch from the bottom of the 2nd receiver. Purge the ethyl iodide formed in the boiling flask into the contents of the 1st receiver by bubbling a slow stream of CO₂ first thru a scrubber tower contg 100ml of concd sulfuric acid and then thru the side arm of the boiling flask at the rate of approx 2 bubbles per sec. Place the flask in an appropriate bath and maintain at 150°C for 40 mins, while collecting the distillate in the 1st and 2nd receivers. Remove the source of heat, stop bubbling CO₂ and wash the contents of both receivers into a 500-ml flask contg 20ml of a soln contg 250g of Na acetate per 1 liter of distd w. Dilute to 125ml with water, add...
FIG E:15 - ETHOXY APPARATUS
90% soln of fomic acid dropwise with swirling until the liquid becomes colorless, and then add 3 drops more. This usually requires a total of 12 to 15 drops. Allow 3 mins for the desired reaction to be completed and then add 25ml of 10% sulfuric acid and 3g of KI. Swirl the mixture and, after allowing to stand for 3 mins (while protected from light), titrate the liberated iodine with 0.1N Na thiosulfate soln using starch as an indicator

\[
% \text{ Ethoxy} = 0.751 \text{ AN/W}
\]

where:

- \( A = \text{ml of Na thiosulfate soln used for specimen} \)
- \( N = \text{its normality} \)
- \( W = \text{wt of specimen, corrected for ash content} \)

3. **Moisture Content** - maximum 2.0% for Class 1 and 2.2% for Class 2

Weigh to the nearest 0.1mg approx 5g of the specimen in a tared short, wide-mouth weighing bottle, equipped with a glass stopper. Heat without stopper for 1 hour at 100 to 105°C, close loosely, cool in a desiccator and weigh. Repeat the heating until constant wt is obtd. Calculate the loss in wt as % of moisture in the specimen.

4. **Acidity** - none in Class 1 and in Class 2

Boil 10.00g of the specimen with 150ml freshly distilled water for 5 mins, allow to settle, and cool. Titrate with weak std KOH (or NaOH) soln using red as an indicator

5. **Chloride Content as NaCl** - maximum 0.02% for Class 2

Weigh 10g of the specimen to the nearest 0.01g and transfer to a 500ml Erlenmeyer flask. Add 150ml of distd w and 40ml of 1:3 soln of HNO₃. Heat the flask to boiling its contents and continue to boil for 2 minutes. Filter thru a Gooch crucible into a flask and rinse the filter and the flask with four 5ml portions of water, into the same flask. Add 5ml of approx 0.1N Ag nitrate soln and 3ml of pure Nitrobenzene, followed by 1 ml of ferric alum soln. Shake vigorously to coagulate the ppt and titrate the excess of Ag nitrate with std 0.1N K thiocyanate soln until a reddish-brown color appears that does not fade in 5 minutes

\[
% \text{ Chloride as NaCl} = \frac{5.845(AB-CD)}{W}
\]

where:

- \( A = \text{ml Ag nitrate soln used} \)
- \( B = \text{its normality} \)

C = ml of K thiocyanate soln used in titration

D = its normality

\( W = \text{wt of specimen used, in g} \)

6. **Viscosity** at 25°C(5% EtCell in 80:20 toluene-ethanol soln) centipoises = 10±1 for Class 1 and 7±1 for Class 2

Dissolve 5.00g of the specimen in 76g of toluene and 19g of ethanol conforming to Spec O=È=760. Determine the viscosity at 25°C according to Method 305 of Federal Test Method Standard No 791, except that the results in centistokes should be converted to centipoises as follows:

\[
\text{Viscosity in centipoises} = \frac{d}{v}
\]

where:

- \( d = \text{density of EtCell soln} \)
- \( v = \text{kinematic viscosity in centistokes} \)

**Note**: Density can be detd by any suitable method accurate to three significant figures, such as pycnometer method described in Vol 3 of Encycl, p D69

7. **Granulation** - maximum 1.0% for Class 2 only, retained on a 2000 micron (No 10) sieve

Weigh approx 100g of the specimen to the nearest 0.1g and place on a No 10 sieve conforming to Spec RR-S-356 and equipped with a cover and a bottom pan. Shake the sieve for 5 mins in a mechanical shaker geared to produce 300±15 gyrations and 150±10 taps of the striker per minute. Weigh the portion retained on the sieve and calculate the % retained

8. **Thermoplastic Point**. Class 1 material shall fuse without charring and be capable of being drawn into a thread at a temp not lower than 145°C

**Procedure**: Fill a ¾x4-inch test tube to a depth of 1 inch with the specimen ground to pass a No 16 mesh screen. Submerge the tube to a depth of 2 inches in an oil bath previously heated to 120°C, place a thermometer in the EtCell and increase the bath temp at the rate of 2°C per min, while stirring the specimen by means of thermometer. At a temp approx 25°C below fusion point the particles soften and tend to cohere, making it difficult to stir. Continue heating and working the mass until it fuses and becomes plastic. Read the "thermoplastic point" as the temp at which the plastic mass can be repeatedly drawn into thread by pulling the thermometer from the mass. Duplicate dems should check within 3°C
Ethyl Centralite or sym-Diethyldiphenylurea. See Centralite 1 or Carbamite in Vol 2 of Encycl, pp C127 to C129. Analytical procedures including tests prescribed by US Joint Army-Navy Specification JAN-E-255 are described on pp C129 to C134

Ethyl Chlorate. See Ethyl Chlorite below


Ethyl Chlorite, C2H5ClO2. The only ref to this compd or the corresponding chlorate reported an attempt to prepare ethyl perchlorite from ethyl iodide and silver chlorite at 15°. No reaction was noticeable until the solution was allowed to warm a little, after which some Agl precipitated. The solution exploded a short while later.
Ref: G.A. Levy, GazzChemItal 53, 40-2 (1923) & CA 17, 2263 (1923)

Ethylchloroacetate, Cl2CH2CO2-C2H5; mw 122.55; colorless pungent liq, sp gr 1.159 at 20°/4, fr pr 26°, bp 144°; flash p 54°C; insol in w; sol in alc, eth or benz. It can be prepd by the action of chloroacetyl chloride on ethanol or by treating chloroacetic acid with ethanol and sulfuric acid. It is used as solvent and as a military poison gas. It was not described under Chemical Warfare Agents in Vol 2 of Encycl.

Ethyl Chlorocarbonate or Ethylchloroformate, Cl.CO2-C2H5; mw 108.53, colorless, toxic, flammable, tear-producing liq; sp gr 1.138 at 20°/4, fr p 80-6.6°, bp 94-5.5°, flash p 61°F (approx); insol in w, but decomp; sol in alc, eth, benz & chlf. It can be prepd by reacting CO with gaseous chlorine, producing phosphene (COCl2) which is then reacted with anhydrus ethanol, giving ethyl chlorocarbonate and splitting off HCl. It is used in organic synthesis as an intermediate in production of diethylcarbonate


Ethyl Chloroformate. See Ethylchlorocarbonate


Ethylcresol and Derivatives
5-Ethyl-2-m-cresol, H5C2-C6H4(CH3)OH; mw 136.19; prisms (from benz), mp 55°, bp 232.5°, 130° at 20mm. It may be prepared from m- or p-cresol and ether in the presence of AlCl3.
Refs: 1) Beil 6, [182] 2) E.C. Horning et al, JACS 71, 169 (1949)

5-Ethyl-2,4,6-trinitro-m-cresol, H5C2-(CH3)C6H4(NO2)3.OH; mw 271.18, N 15.50%, OB -56.0%, crystals (from petr eth), mp 67.0°. It may be prepd by dissolving 3-methyl-5-ethylenol in sulfuric acid and adding nitric acid, drowning on ice, and recrystallizing.

Ethyl Cyanide or Propionic Nitrile, C2H5-CN; mw 55.08; colorless, toxic liq with ethereal odor; sp gr 0.7829 at 20°/20, nD 1.3664, fr p -91.9°, bp 97.2°, flash p 61°F (open cup); insol in w; sol in alc & eth. It can be prepd by heating Ba ethyl-sulfate with KCN, followed by distillation. It is used as solvent, dielectric fluid and as an intermediate.

Ethyl cyanooacetate or Cyanacetic Ester, NC.CH2.C2O2.C2H5; mw 113.11, colorless liq, sp gr 1.062 at 20°/4, fr p 22.5°, bp 208° at 753mm; sl sol in w & in alkaline solns; sol in alc & meth. It can be prepd by esterification of cyanooacetic acid with ethanol or by reaction of an alkali cyanide with chloroacetic ethyl ester. It is used in org synthesis
Ethylcyanoformate. A Chemical Warfare Agent listed in Vol 2, p C169-R as item t)

Ethylcyanomethylamine and Derivatives

N-Ethyl-N-cyanomethylamine (Also called Ethylcyanohydrazide), \( \text{C}_2\text{H}_5(\text{N}_2\text{H})\text{CN} \); mw 84.12, N 33.30%. It may be prepared from ethylimidazole and BrCN which give Et(Me)N+C\( ^+ \text{CN} \)Br\(^- \). Heating gives Et(Me)NC\( ^+ \text{CN} \) and CH\(_3\)Br.


N-Trinitroethyl-N-cyanomethyl Nitramine,

\( (\text{O}_2\text{N})_3\text{C}.\text{CH}_2.\text{N}(\text{CH}_2.\text{CN}).\text{NO}_2 \); mw 265.12, N 31.63%; crystals, mp 81-82°, d 1.75g/cc, ignition temp 194°, impact sensitivity 11cm with 2½kg wt, thermal stability 16.8cc/g at 90°. Its method of prep was not reported in Ref 2. This compound was not of interest due to its poor thermal stability.

Ref: 1) Beil, not found 2) D.L. Kouba et al, HerculesPowdCo Progress Rept, May 1952 (Contract NOrd-11280, Task A)

1-Ethylcyclohexyl Hydroperoxide-p-Nitrobenzoate,

\( (\text{C}_2\text{H}_5)_2\text{C}(\text{CH}_3)\text{O}_2.\text{CO.C}_6\text{H}_4.\text{NO}_2 \); mw 293.33, N 4.77%; mp 68-9°; expl in a flame. Criegee & Dietrich (Ref 2) treated 1-ethyl cyclohexanol with 8% hydrogen peroxide and 0.2cm concd sulfuric acid for 14 hrs at 0° and purified the Na salt. The peroxide and p-nitrobenzoyl chloride in abs pyridine gave the nitrobenzoate as yellow plates from ether or methanol.

Ref: 1) Beil, not found 2) R. Criegee & H. Dietrich, Ann 560, 139 (1948) & CA 43, 6189 (1949)

Ethyldiaminomethane and Derivatives

Ethyl-diaminomethane or N-Ethyl-methylene-diamine, \( \text{C}_2\text{H}_2.\text{NH}.\text{C}_2.\text{NH}_2 \); called N-Ethylmethanediamine in CA and \( \text{C}_2\text{H}_2.\text{CH}(\text{NH}_2).\text{C}_2.\text{NH}_2 \), called Propylene-1,2-diamine, mw 74.12, N 37.79%. Ref: 1) Beil, not found 2) CA, not found

NOTE: The nitratated compd, \( \text{C}_2\text{H}_2.\text{CH}(\text{NH.NO}_3).\text{C}_2.\text{NH.NO}_3 \), listed below, is also found in Vol 5, p D1142-R under 1,2-Dinitropropene or Propylenedinitramine

N-Ethyl-N',N'-dinitroaminomethane or N-Ethylmethylenedinitramine,

\( \text{C}_2\text{H}_2.\text{CH}_2.\text{N}(\text{NO}_2).\text{C}_2.\text{NH}(\text{NO}_2) \); mw 164.13, N 34.14%, OB to CO\(_2\) -58.5%. This compd is an expl having 118% the power of TNT by ballistic mortar test. It is listed by Blatt as Trimethylene-1,3-dinitramine.

Blatt (Ref 2) also lists Trimethylene-1,2-dinitramine or Propylene-1,2-dinitramine (PDNA) with the formula, \( \text{C}_2\text{H}_2.\text{CH}(\text{NH.NO}_2).\text{C}_2.\text{NH}(\text{NO}_2) \), crystals, mp 108.5-110°; solubilities - not given. It can be prepared by treating \( \text{CH}_3.\text{CH}(\text{NH}_2).\text{CH}_2.\text{NH}_2 \) with CICOOC\(_2\)H\(_5\) (ethyl chlorocarbonate) to obtain \( \text{CH}_3.\text{CH}(\text{NH}.\text{CO}_2\text{C}_2\text{H}_5).\text{CH}_2.\text{NH}.\text{CO}_2\text{C}_2\text{H}_5 \), followed by nitration & hydrolysis.

It is an expl compd, possessing the following properties:

Hygroscopicity at 25°: gained 0.76% at 90% RH and 2.42% at 100% RH; Ignition Temperature 355°; Impact Sensitivity with 2kg wt using Bruceton No 3 Machine - 50% positive at 65cm drop; International Test at 75° - lost 2%; Power by Ballistic Mortar - 116% TNT; Power by Traul Test - 123% TNT; Stability at 100° - not acid in 300 mins; Vacuum Stability at 100° - lost >12cc/5g in 24 hours (Ref 2 & 3)

Ref: 1) Beil, not found 2) Blatt, OSRD 1944 (1944), under Trimethylene-1,2-dinitramine, taken from NDRC, Div 8, Interim Rept PT-9, Apr 15 to May 15, 1943, p 29 3) ADL, Pure-ExplCompds, Part 1 (1947), p 34

Ethylazaoctahydrodiamine and Derivatives

Ethylazoheptanoate,

\( \text{C}_2\text{H}_2.\text{CH}_2.\text{C}_2.\text{NH}.\text{CH}_2.\text{NH}.\text{CO}_2\text{C}_2\text{H}_2.\text{CH}_3 \); may be considered as the parent compd of its nitratated derivs, although not used to prep them.
2,2,2-Trinitroethyl-4,6,6-trinitro-2,4-diazaheptanoate, CH₃C(NO₂)₂CH₂N(NO₂)₂CH₂-NO₂
CH₃-C-CH₂N-CH₂N-COO.CH₂C(NO₂)₃;

MW 475.21, N 26.53%;
wh crystals (from ethylene dichloride); mp 140–41°C; impact sensitivity ~ 25 cm with 2 kg wt;
propellant by Pb block 167% (calcd) & by ballistic mortar 144% TNT (calcd)

This compound was prepared by adding dropwise the above trinitro deriv to acetic anhydride to
100% nitric acid cooled to 5°C. The soln was
stirred for 20 min at 5°C and poured onto ice
(Ref 2). Heat of combustion 1806 kcal/g (Ref 2)

Other props reported are crystal d 1.79,
hot bar ignition temp 219°C, sensitivity - same
as Pentolite (Ref 3)

Ref: 1) Beil, not found 2) L.T. Carleton
& M.B. Frankel, AerojetGeneral Corp Quarterly
Rept 111 (June 1953), 10–12 3) D.V. Sickman
& W.F. Sager, NAVORD Rept 489 (1954)

Ethyl Diazide. See Ethane Diazide in this Vol

Ethyl Diazidomalonate. See Ethyl-bis(triazomalonate) in this Vol

Ethyl Diazidomalonate. See Ethyl-bis(triazomalonate) in this Vol

Ethyl Diazidomalonate. See Ethyl-bis(triazomalonate) in this Vol

Ethyl Diazatoacetate or Diazooethylacetate,
N₂:CH,CO₂.C₂H₅; MW 114.10; Yel oil (which is easily converted to solid modification),
sp gr 1.085 at 18°C/4, fr p -22°C, bp 140–41°C
at 720mm; sl sol in w; sol in alc & eth. It
can explode during vacuum distillation; may
be prepared by diazotization of ethyl glycinate
with HCl and NaN₃ or by reaction of ethyl
glycinate.HCl, NaNO₂ and 10% H₂SO₄ in
ether or chlf

Ref: 1) Beil 25, 110; 3 (211), [390] & [1140]
2) J.A.S. Hammond, USP 2691649 (1954) &

CA 49, 11690 (1955); USP 2691650 (1954) &
CA 49, 11691 (1955) 3) P. Yates, B. Shapiro,
N. Yoda & J. Fugger, JACS 79, 5756–60 (1957)

Ethyl Diazosuccinate or Diazooethylsuccinate,
C₄H₆O₂.C₂H₅.C(NO₂)₂CO₂.C₂H₅; MW 200.19,
N 13.99%; Yel liq, crysts (from a cold mixt of
eth & petr eth), bp 77–78°C at 0.1mm press;
sp gr 1.139 at 20°C, 63 1.4620 at 20°C

An attempt to prepare ethyl diazosuccinate
from ethyl diazosuccinate and liq NH₃
resulted in a violent expln (Ref 2). Ethyl
diazosuccinate is prev by diazotization of
diethylaminosuccinate (Ref 1)
Ref: 1) Beil 25, 159; 3, (274), [479] & [1364]
2) A. Darapsky, Ber 43, 1102 (1910) & CA 4,
2466 (1910)

Ethyl Dichloramine. See N,N-Dichloroethylamine in Vol 5, p D1210-R

Ethyl Dichlorosulfide. See Chemical Warfare Agent ED in Vol 2, p C167-R

Ethyl Diethanolamine and Derivatives
Ethyl Diethanolamine (EDcaA),
C₄H₉N(CH₂CH₂OH)₂; MW 133.19, N 10.52%,
coldless liq with amine odor, sp gr 1.015 at
20°C, bp 1466°F at 20°C, bp 251–52°C, flash p
255°F, sol in water & alc; prep by adding
ethylene oxide to a cold solution of ethylamine.

It is used as solvent and in detergents
Ref: 1) Beil 4, 284 2) L. Knorr & W. Schmidt,
Ber 31, 1074 (1898) 3) CondChemDict (1961),
464-L

Ethyl Diethanolamine, US Military Requirements
and Tests, as described in Specification MIL-
E-10660B (Cm1C), 27 Apr 1959. Accdg to
Notice 1, 3 Feb 1972, the material covered by
the spec was used in the production of Nitrogen
Mustard, HN–I, which is obsolete. Neverthe-
less, it is of interest to describe this Spec
REQUIREMENTS AND TESTS:
1) Appearance. It shall be a clear, orange to light straw in color, liquid, free from all visual suspended matter or deposit. A composite sample shall be examined visually.

2) Specific Gravity at 20/20° = 1.015 to 1.025 g/cc. It shall be determined by means of a pycnometer in accordance with Method 4183 of Federal Test Method Standard No 141.

3) Nitrogen Content — 10.36 to 10.57%. It shall be determined by the Kjeldahl Method. Weigh in a thin glass bulb ca 0.4 g of material to the nearest 0.1 mg. Place it in a 500 ml Kjeldahl flask, add 10 ml of concd sulfuric acid and cool in an ice bath. Break the bulb with the flattened end of a long glass rod making sure that the bulb and its stem are completely crushed. Rinse the rod with 20 ml of concd sulfuric acid, add 10 g of powdered K$_2$SO$_4$ (or anhydrous Na$_2$SO$_4$) and 0.5 g of powdered CuSO$_4$ (or 0.3 g of selenium) or a suitable combination of the catalyst.

Note: Mercuric oxide, 0.78 g, or an equivalent amt of Hg may replace copper sulfate or Se, but in this case Na$_2$S must also be added later to remove the mercury before the distillation, thus preventing the formation of mercury-amido complexes which are not completely decomposed when treated later by NaOH soln.

Next, add 20 ml of sulfuric acid, pouring it slowly down the neck so that any of the sample adhering to the neck of the flask is washed down. Incline the flask at an angle of ca 45° and gently heat over a free flame or electrically until frothing has ceased. Increase the heat until the acid boils briskly and continue heating until the liquid either acquires a clear green color or becomes nearly colorless. This takes about 30 mins. Cool and cautiously add 150 ml of water, cool again, and then add 100 ml of a 30% NaOH soln poured down the side of the flask so that it does not mix with the acid soln. Add a few pieces of granulated Zn and connect the flask, at once, by means of a rubber stopper, to the Kjeldahl distillation apparatus.

Note: An alternate procedure is to add the alkali thru a small separatory funnel passing thru a 2nd hole in the stopper. No loss of ammonia can result with this method.

Then mix the layers carefully by rotating the flask, and distil ca 200 ml into a 500 ml flask contg 50 ml of 0.1 N hydrochloric acid, and 6 drops of indicator soln (0.9 g of Na alizarin sulfonate with 0.125 g of indigo carmine dissolved in 100 ml of water). Rinse the adapter into the receiving flask and titrate the excess acid with standardized 0.1 N NaOH to the gray transition point of the indicator (pH = 5.4). Calculate as follows:

\[
\% \text{ Nitrogen} = \frac{1.401(\text{AB} - \text{CD})}{\text{W}}
\]

where:

A = ml of HCl
B = normality of HCl
C = ml of NaOH soln
D = normality of NaOH soln
W = weight of sample

4) Water Content, as Received — 0.20%, maximum. Determine its content in accordance with Method No 3001 of Federal Test Method Standard No 791.

5) Distillation Range — 240° to 270° and Total Distillate Between 240° & 265° — 96.0% minimum.

Use Method 1001 of Federal Test Method Standard No 791, except that, due to the high viscosity of the material, cooling water at 40°-45° shall be substituted for the ice-water in the condenser.

6) Rejection Criteria. If composite specimen fails to conform to this specification, the lot represented shall be rejected.

Ethyl(dimethylanilino)methanilines or Ethylaminoxylene. See N-Ethylxylidines in this Vol.

N-Ethyl-(dimethylphenyl)amine or N-Ethyl-dimethylaniline and Derivatios (ÁEthylicvic-o-xylidin in Ger),

N-Ethyl-2,3-dimethylaniline,

(CH$_3$)$_2$C$_6$H$_4$NH.C$_2$H$_5$; mw 149.24, liq, bp 227-28°. It is prep'd by hydrolysis of the corresponding acetamide with 40% H$_2$SO$_4$.

N-Ethyl-2,6-dimethylaniline (ÁEthylicvic-m-xylidin in Ger), mw 149.24, bp 217-18°, oil smelling of camphor. It is prep'd by reacting vic-m-xylidine with EtBr and NaOH at 180°.

N-Ethyl-2,5-dimethylaniline (ÁEthylic-p-xylidin in Ger), mw 149.24, bp 222-23° (748 torr), oil smelling of naphthaene. It is prep'd by hydrolysis of the corresponding benzene sulfonate with concd HC1 at 150°.

Ref: Beil 12, 1101, 1109, 1137
N-Ethyl-2,3-dimethyl-4,6-dinitroaniline, 
(CH)_2C_6H(NO_2)_2.HCl.C_2H_5; mw 239.23, N 17.57%; om ndls, mp 75-6 °C. It is prepd from ethylamine and the 3,4,6-trinitro cmpd. 

N-Ethyl-3,4-dimethyl-2,6-dinitroaniline, mw 239.23, om ndls, mp 115 °C, sol in benz, chl; prepd from ethylamine and the 3,4,5-trinitro cmpd. 

N-Ethyl-2,5-dimethyl-4,6-dinitroaniline, mw 239.23, mp 133 °C; prepd from ethylamine and the trinitro cmpd 
Refs: 1) Beil 12, 1141 & [618] 2) J.J. Blanksma, RecTravChim 24, 51 (1904) 

N-Ethyl-3,5-dimethyl-2,4,6-trinitroaniline, 
(CH)_2C_6H(NO_2)_3.NH.C_2H_5; mw 284.23, N 14.78% (NO_2), mp 122 °C; prepd from ethylamine and the corresponding methoxytrinitro cmpd. 
Refs: 1) Beil 12, 1133 2) J.J. Blanksma, RecTravChim 21, 331 (1902) 

N-Ethyl-N-nitro-3,6-dimethyl-2,4-dinitroaniline, [Ethyl-(dinitrodimethylphenyl)nitramine], 
(CH)_2C_6H(NO_2)_2.N(NO_2).C_2H_5; mw 284.23, N 14.78% (NO_2), cryst (from alc, HNO_3 or acet ac), mp 36 °C. It is prepd by nitration of the already ring nitratrd cmpd. 
Refs: 1) Beil 12, 1141 2) J.J. Blanksma, RecTravChim 24, 51 (1904) 

N-Ethyl-N-nitro-3,5-dimethyl-2,4,6-trinitroaniline, [Ethyl-(trinitrodimethylphenyl)nitramine], 
(CH)_2C_6H(NO_2)_3.N(NO_2).C_2H_5; mw 329.24, N 17.02% (NO_2), colorless crys, mp 85 °C. It is prepd by nitration of the already ring nitratrd cmpd. 
Refs: 1) Beil 12, 1134 2) J.J. Blanksma, RecTravChim 21, 331 (1902) 

2-Ethyl-1,3-dimethyl(propanediol). See 1,1-Di(methylol)-propane in Vol 5, p DI358-R 

Ethylidiphenylamine and Derivatives 
N-Ethylidiphenylamine, C_6H_5.N(C_6H_5).C_2H_5; mw 197.18, liq, sp gr 1.048, bp 295-97 °C; 150 °C (10mm); insolv in w, sol in alc. It can be prepd by reacting EtBr with diphenylamine and KNH_2. 
Refs: 1) Beil 12, 181 & [105] 

N-Ethyl-1-nitrophenylamine, 
C_6H_4(NO_2).N.C_6H_5; mw 242.27, N 11.56%; om blades, mp 50-51 °C. It is prepd from 1-nitrophenylamine, ethyl sulfate and base. 

N-Ethyl-4-nitrophenylamine, mw 242.18, yel, mp 87-88 °C. It is prepd from 4-nitrophenylamine, ethyl iodide and base. 

N-Ethyl-2,4-dinitrodiphenylamine, 
C_6H_5.N.C_6H_4(NO_2)_2; mw 287.28, N 9.75% (NO_2); mp 95 °C (97.5 °C), sp gr 1.364, red prisms (alc); sol in HAc, alc, ligroin, benz; sl sol in hot w & eth. It is prepd from ethyl aniline and 4-chloro (or bromo)-1,3-dinitrobenzene with NaAc (or boiling in alc). 
Refs: 1) Beil 12, 753, (362) 2) J. Forrest et al, JCS 1946, 454-6 & CA 41, 405b (1947) 

N-Ethyl-2,4,6-trinitrodiphenylamine, 
C_6H_5.C_6H_4(NO_2)_3; mw 333.085, N 12.62%; red crys, mp 105-0 °C. It is prepd from picryl chloride and ethyl aniline in alc. 
Refs: 1) Beil 12, 766 & (370) 2) A. Hantzsche, Ber 43, 1678 (1910) 

N-Ethyl-hexanitrodiphenylamine or N-Ethyl-dipicrylamine, C_6H_5.N:[C_6H_4(NO_2)_3]_2; mw 467.27, N 20.98%, OB -70.2%, wh ndls, mp 198-200 °C, 201-202 °C, sol in acetone & EtAc; prepd from reaction of nitric acid with N-Et-N-phenyl-2,4-dinitroaniline. 
Refs: 1) Beil 12, 766 2) A. Mulder, RecTravChim 25, 122 (1906)
N'-Ethyl-N,N-diphenylurea. See Acardite III (Ethylacardine) in Vol 1, p A8-R

ETHYLENE AND DERIVATIVES

Ethylene (Ethene or Elay), H₂C=CH₂; mw 28.05; colorless, flammable, dangerous to handle gas with characteristic sweet odor and taste; sp gr 0.975 (air = 1.0), mp -169.4⁰, bp -103.8⁰, flash p -136⁰C; explosive limits in air, % by vol, lower 3.0 & upper 34.0; sl sol in w, more in alc; sol in eth. Ethylene is a major component of petroleum refinery gas from cracking units, and is sometimes recovered therefrom by distillation or other means. Some pure ethylene is produced by passing hot ethanol vapors over a catalyst, such as activated alumina (Ref 4). Its laboratory prep consists of heating ethanol in definite proportions with sulfuric acid of certain concns. By using a 90% acid and 90% alc, ethylene can be produced in a regular stream at a yield of 84 to 85% of theory (Ref 2).

Accdg to footnote 11 in Ref 2, p 212, ethylene was manufd in the US by passing ethanol vapor over coke wet with phosphoric acid in towers. Use: The source of many ethyl and ethylene compounds, such as synthetic ethyl, ethylene-glycol, styrene; also in oxyethylene welding and cutting of metals (Refs 4 & 5).

Kume (Ref 3) obtd on heating to 245⁰ and at 1600kg/sq cm pressure of liquid ethylene (contg 0.02 to 0.06% oxygen) a polymerization product, which was white, spongy, wax-like solid melting at 107-10⁰. Heating too rapidly could produce an expn.


Ethylene-Carbon Tetrachloride Explosions. Accdy to Bolt (Ref 1), ethylene (5.6 moles) was gradually introduced into a 2600-ml autoclave contg 17.6 moles carbon tetrachloride and 0.45 moles benzoyl peroxide, serving as reaction initiator. The pressure was kept below 2500psi. After about 2 hours an expn occurred at 67⁰, discharging most of the reactants thru the unpured safety disk.

Note: A previous alkylation of CCl₄ with 1,3-butadiene was performed without mishap.

Joyce (Ref 2) described three examples of uncontrolled reactions between ethylene and CCl₄, two of them resulting in violent explns. In each case benzoyl peroxide was the initiator. Precautions essential for avoiding explns appear to be restriction of reaction rate and adequate dissipation of the heat of reaction. The quantity of reaction initiator should be kept at a minimum.


Ethylene Chloride. See Ethylene Dichloride

Ethylene Dichloride; 1,2-Dichloroethene or Dutch Oil, Cl₂H₂Cl₂; mw 98.97; col oily liquid; sp gr 1.2554 at 20/4⁰, mp 1.444, fr p 35.5⁰, bp 85.5⁰, flash p 70⁰C; sl sol in W; v sol in alc, eth & chl. Was first propd in 1795 by Dutch chemists; prepd now by the action of chlorine on ethylene with subsequent dist.; its industrial method of prepn was patented in 1915 in Germany (Ref 2 & 3). It is stable in the presence of water, alkalis, acids, or actively-reacting chemicals and is resistant to oxidation. Will not corrode metals. Its vapors are poisonous.

Used as solvent for fats, oils, waxes, cellulose esters and ethers, rubber, "Bakelite", resins, gums and other products; also as scavenger for TEL (tetraethyl lead) in gasoline. Considerable amt was produced in Germany during WWII, because on mild saponification (such as with Na bicarbonate) it gave ethylene-glycol, while saponification with alkalis produced vinyl chloride, and finally acetylene (Refs 3&4).


Ethylene(ETHENE) Explosive Decomposition. Workers in Holland have observed that C₂H₄ under certain conditions and especially in the presence of AlCl₃ as catalyst and finely divided Ni as promoter, may decomp vigorously or even explode into its elements. It has been found that some solvents for AlCl₃ promote.
polymerization of C₂H₄. The following cmpds have been involved in expln of C₂H₄ at temps and pressures of experiments described in Ref: C₃H₉, CH₃Cl and CH₃NO₂

Ethylene Reaction with NO₂. Investigation at the laboratory of US Rubber Co (Ref 2) showed that when ethylene was treated with N₂O₅ by the method of Levy & Scaife (Ref 1), the following cmpds were obt: 1,2-Dinitroethane, Nitromethylnitrate and Nitroethanol.

A process is described for producing aliphatic nitrates or nitro cmpds from the corresponding nitrites or nitro cmpds by oxidation with NO₂ or O and N₂O₃ or NO. Thus, pure dry CH₂:CH₃ and 15% of its vol of O were passed into liq NO₂ over a period of 7 hrs, the reaction mixt was withdrawn, degassed, and poured into cooled MeOH. Solid O₃N.CH₂:CH₂:NO₂ was thrown out and separated by filtration. The MeOH was removed from the filtrate, the residual oil treated on vacuum pump and extracted by a mixt of benz & water. The aq layer was neutralized, extracted with ether and the remainder distilled to give 2-nitroethanol. The benz layer gave O₃N.CH₂:CH₂ONO₂


Ethylene Azide or Vinyl Azide. See Azido-ethylene in Vol 1, pA638-L

Ethylene Nitrite See Ethylene Dinitrite

Ethylene Nitrate. See Ethylene Dinitrate or Ethyleneglycol Dinitrate

Nitroethylene (NEt) H₂C:CH.NO₂; mw 73.05, N 19.17%; It yel-green liq with lachrymatory props and sharp penetrating odor; sp gr 1.073 ag 13.8°, bp 39° at 70mm or 98.5° at 745mm; sol in water and in some organic solvents. It was prepd in small yield by Wieland & Sakelarios (Ref 2) using direct dehropy of 2-nitroethanol by means of anhydrous Na bisulfate. Much better results were obtd by theol decomp of 2-Nitroethanol benzolate, when carried out in a Claissen flask at 180-230°. The flask was covered with friction tape to exclude light. Buckley & Scaife prep'd it by dehydrating 2-Nitroethanol with phthalic anhydride (Ref 3). Nema (Ref 4) prep'd it from CH₃NO₂HCHO through intermediate formation of O₃N.CH₂:CH₂:OH, followed by dehydration with KH₂PO₄ as a catalyst. This gave a liquid compd, but if dehydration were done with H₂PO₄ as catalyst polymerization took place to form a tough solid. Boileau & Runavor (Ref 5) described a laboratory method using activated alumina and silica gel for dehydration. NEt easily forms a polymer, which is described below


Nitroethylene Polymer (NEtPol) [H₂C:CH.NO₂]₄; mw [73.05]ₜ, N 19.17%, OB to CO₂ 7%; wh amorphous solid, mp did not melt, but decmpd slowly at 75°, igniting after 2 hours of heating; being heated at 100°, it deflagrated with evofil of a brown sooty smoke; when placed on a hot plate heated at 200°, it spontaneously decomposed without expln. Small amts dropped on a red hot plate burned with a gentle puff. In the folds of comb-
ustible paper, it burned rapidly and smoothly. When wrapped in tin foil and hammer ed on an iron base, it did not explode. Qualitative capillary tests in a sealed tube indicated that it is a weak explosive.

\text{N}E\text{t}P\text{ol} is very sl sol in w; more sol in some org solvents including cyclic ketones; sol in hot alkalis forming a yel liquid; insol in di-nedylformamide

It was prepbd by Wieland & Sakellarios (Ref 2) by emulsifying monomeric 2-\text{N}E\text{t} in an aqueous medium (neutral or slightly alkaline). A sim similar method was used by Buckley & Scaife (Ref 4). Blatt (Ref 3) lists a method of prep from 1-chloro-2-nitroethane and Na bicarbonate in 76\% yield, developed during WWII in USA. Noma (Ref 5) prep from the polymer from Nitromethane and formaldehyde thru intermediate formation of Nitroethanol, followed by dehydration with \text{H}_3\text{PO}_4\text{ catalyst}

Following is laboratory method of prep developed during WWII in USA: Agitate mechanically a 3-neck 500-ml flask conctg 300-ml of freshly distd w, 2g calgon (emulsifier) and 5 drops of ascaridole. After displacing the air in the flask, with 0-free nitrogen, add gradually 10g of freshly prepbd Nitroethylene and continue agitation for 2 hours. Filter off the coagulated solid material and dry. Yield 91\%

Blatt (Ref 3) lists the following props of \text{N}E\text{t}Pol:

\text{Hygroscopicity at 25\%} gains 2.6\% at 90\% RH and 14\% at 100\%

\text{Impact Sensitivity} - comparable with TNT

\text{International Test at 75\%} ignites after 105 mins

\text{Power by Ballistic Mortar Test} - 29\% of TNT

\text{Thermal Stability at 100\%} - deflagrates in 23 mins

\text{Uses} - no information

\text{Refs:} 1) Beil, 1, (82) 2) W. Wieland d & E. Sakellarios, Ber 52, 901 (1919) & CA 13, 2874(1919) 3) Blatt, OSRD 2014(1944)

4) G.D. Buckley & C.W. Scaife, JChemSec 1947, 1471-72 & CA 42, 4907 (1947)

5) K. Noma, Chem High Polymers (Japan) 5, 99-103 (1948) & CA 46, 4471 (1952)

\text{Nitrosoethylene,} \text{H}_2\text{C}=\text{CHNO}; \text{mw} 57.05, \text{N24.56\%}. Hypothesized as intermediate in the reaction of ethylene with NO\textsubscript{2} (Ref 2)

\text{Refs:} 1) Beil, not found 2) T. Takeuchi, Shokubai No 8, 37-46 (1952) & CA 47, 11916 (1953)

\text{Ethylene Dinitrite.} Same as Ethyleneglycol Dinitrite or Glycol Dinitrate, described under Ethyleneglycol and Derivatives

\text{Ethylene Dinitrate.} Same as Ethyleneglycol Dinitrite or Glycol Dinitrate, described under Ethyleneglycol and Derivatives

\text{Ethyleneamine.} The name given in Cond ChemDict (1961), 464 to Diethylenediamine or Piperazine described in Vol 5, pp D1230-R & D1231. Compare with Ethylenediamine

\text{Ethyleneaminoxide and Derivatives} \text{Ethylenediaminoxide,} \text{H}_3\text{C.C}(\text{NH}_3):\text{NOH}; \text{mw} 74.08, N 37.81\% ; ndls (alc + eth), mp 135\% (dec), sol in water, alc; insol in eth & chl; unstable. It is prepbd from hydroxylamine and acetonitrile with Na\text{OEt} (Ref 2)

\text{Refs:} 1) Beil 2, 188 2) E. Nordmann, Ber 17, 2746 (1884)

\text{Nitroethylenediaminoxide,} \text{(O}_2\text{N})\text{H}_2\text{C.C}(\text{NH}_3):\text{NOH}; \text{mw} 119.08, N 35.29\% ; yel solid, mp - decmp violently when heated to about 108\%. It can be prepbd by action of Amm nitroacetonitrile on \text{NH}_2\text{OH.HCl}

\text{Refs:} 1) Beil 2, 227 & (100) 2) W. Steinkopf & L. Boehm, Ber 41, 1044-52 (1908) & CA 2, 1962 (1908)

\text{Ethylenebisacetamide and Derivatives} \text{Ethylenebisacetamide} (Called Diacéthyethylendiamine by Franchimont), \text{H}_3\text{C.CO.NH.CH}_2=\text{CH}_2\cdot\text{NH.CO.CH}_3; \text{mw} 144.17, N 19.43\%; crys, mp 172-73\%; sol in alc & water. It was first prepbd by Linnewe- man in 1870 (Ref 1) by heating acetamide with acetic anhydride for 6 hrs at 250\%. Later Franchimont & Dubsky (Ref 2) prep it by heating to boiling the above substances in the presence of metallic Na. Bachmann (Ref 3) prep it by adding 750ml acetic anhydride to 280ml of 64\% aqueous ethylenediamine with stirring and cooling. The resulting clear soln was concentrated on a steam bath, while passi
a current of air, and then mixed with an equal volume of acetone and cooled. The pptd crysts
(first crop, 403g) had mp 172–73°, while the 2nd crop (112g) was of lesser purity.

Nitratin gave the dinitroderivative described below.

Refs: 1) Beil 4, 253 & (416) 2) A.P.N.

Franchimont & J.V. Dubasky, Rec 30, 184(1911)

3) W.E. Bachmann et al, JACS 72, 3133(1950)

& CA 44, 10656(1950)

\[
\text{N,N'-Dinitroethylenesacetonamide,}
\]

\[
\text{H}_3\text{C.CO.N(NO}_2\text{).CH}_2\text{CH}_2\text{N(NO}_2\text{).CO.CH}_3\text{; mw 234.17, N 23.93%; col plts, mp 135.5–136°}
\]

(decomp); (132–133° for crude product); solubilities – not given. It was prepd by Bachmann et al in 83% yield in the following manner:

Prepare the nitrating acid just before use by slowly adding with stirring 40ml of acetic anhy-

dride to 40ml of 98% nitric acid cooled in an ice-salt bath to 5° or below. Add gradually to

this mixture (while stirring it and keeping at 5° or below) 15g of ethylenesacetonamide.

Continue stirring for 5 hours keeping at 5° or below and then pour the mixture into 250ml of

ice-water. Separate the ppt by filtration, wash it with water and crystallize from acetone.

This should give about 20.1g of Dinitroethylenesacetonamide.

When 10g of dinitrocompd was stirred with

27ml of concd Amm hydroxide, the EDNA (Ethylenedinitramine) was obtd in 91% yield

Refs: 1) Beil, not found 2) W.E. Bachmann et al, JACS 72, 3133(1950) & CA 44, 10656(1950)

\[
\text{N,N'-Ethylene-bis(anthranilonitrile) and Derivatives}
\]

\[
\text{N,N'-Ethylene-bis(anthranilonitrile),}
\text{CH}_2\text{NH.C}_2\text{H}_4\text{CN; mw 270.27, N 23.68%}
\]

Refs: 1) Beil, not found 2) CA, not found

\[
\text{N,N'-Ethylene-bis(nitroanthranilonitrile),}
\text{C}_6\text{H}_4\text{N}_2\text{O}_4\text{; mw 352.30, N 23.86%. Two}
\]

isomers are known:

\[
\text{N,N'-di(2-Nitro-4-cyanophenyl)-ethylenedi-}
\]

amine (Blankska) or 4,4'-Ethylene-bis(3-

nitrobenzonitrile) (CA Index),

\[
\text{HN.CH}_2\text{—CH}_2\text{NH}
\]
yel crysts, mp > 360°; prepd by heating a soln

of 1-chloro-2-nitro-4-cyanobenzene & ethylenedi-

amine hydrate in alc for 5 hrs in a sealed

tube. The reaction product was allowed to

stand for several hrs with a lukewarm soda

soln, from which the pure product was sepa-

rated (Ref 2)

\[
\text{N,N'-bis(2-cyano-4-nitrophenyl)-a,β-diamino-
}
\]

ethane (Hartmans) or N,N'-Ethylene-bis(3-

nitroanthranilonitrile) (CA Index),

\[
\text{HN.CH}_2\text{—CH}_2\text{NH}
\]
yel crysts having a sandy taste, mp > 360°;

was prepd by heating 1-chloro-2-cyano-4-

nitrobenzene & a,β-diaminoethane in alc in

a sealed tube for 3 hrs. On cooling the crys-

t product was obtd (Ref 3)

\[
\text{N,N'-Ethylene-bis(nitroanthranilonitrile),}
\text{C}_6\text{H}_4\text{N}_2\text{O}_4\text{; mw 442.30, N 25.34%. Two}
\]

isomers are known:

\[
\text{N,N'-di(2,6-Dinitro-4-cyanophenyl)-ethylene-}
\]

amine (Blank ska) or 4,4'-Ethylene-bis(3,5-

nitrobenzonitrile) (CA Index),

\[
\text{HN.CH}_2\text{—CH}_2\text{NH}
\]
yel crysts, mp 282°; was prepd when a soln

of 1-methoxy-2,6-dinitro-4-cyanobenzene &

ethylenediamine hydrate in alc was boiled

with a reflux condenser for 3 hrs on a water

bath. On cooling the product precipitated

(Ref 2)

\[
\text{N,N'-bis(2-Cyano-4,6-dinitrophenyl)-a,β-}
\]

diaminoethane (Hart mans) or N,N'-Ethylene-

bis(3,5-nitroanthranilonitrile) (CA Index)

\[
\text{HN.—CH}_2\text{—CH}_2\text{—NH}
\]
yel tasteless crysts (from alc), mp 239°;

was prepd when a mix of 1-methoxy-2-

cyano-4,6-dinitrobenzene and a,β-diamino-

ethane in alc was boiled under reflux for

3 hrs. On cooling the product separated

(Ref 3)
N,N′-Ethylendinitramine-bis(nitroantranilono-nitrile), C₁₄H₁₂N₂O₆; mw 520.29, N 26.92%. Two isomers are known: N,N′-di(2,6-Dinitro-4-cyanophenyl)-ethylenedinitramine (Blanksma) or 4,4′-[Ethylene-bis(nitromino)]-bis(3,5-dinitrobenzonitrile) (CA Index)

```
O₂N  \ N—CH₂—CH₂—N.NO₂
   \    \     \      
   CN     O₂N     CN     NO₂
```
colorless plates (from acet + alc), mp 203–04° (dec); when heated in a sealed capillary in a flame, the compd exploded. It was prep'd by nitratng with anhyd nitric acid the above 2-nitro deriv or the 2,6-dinitro deriv. A mixed mp of the two products showed the substances to be identical (Ref 2)

N,N′-bis(2-Cyano-4,6-dinitrophenyl)-α,β-dinitroethane (Hartmans) or N,N′Ethylene-bis-(N,3,5-trinitroanilino-nitrile) (CA Index)

```
O₂N  \ N—CH₂—CH₂—N.NO₂
   \    \     \      
   CN     O₂N     CN     NO₂
```
yel tasteless crysts (from alc), mp 145°; was prep'd by nitratng the 2-cyano-4-nitro deriv above with abs nitric acid. Nitration of N,N-bis(2-cyano-4,6-dinitrophenyl)-α,β-diaminoethane with abs nitric acid gave it yel crysts melting at 218°, indicating a purer product


2,2'-Ethylene-bis(4,6-diamino-5-triazene) or Succinoguanamine,
[N=N(C(NH₂)₂)N=C(CH₂)₄]₂; mw 248.25, N 56.42%; mp over 350°. It was prep'd by reacting diethyl succinate with biguanide in 75% yield

Refs: 1) Beil, not found 2) J.T. Thurston, USP 2427515 (1947) & CA 42, 1972 (1948)

Ethylene-bis(N,N-diphenylurea) or Bis(diphenylcarbamy)-ethylenediamine,
(C₆H₅)₂N.CO.NH.C₂H₅.C₂H₅.NH.CO.N(C₆H₅)₂; mw 450.52, N 12.44%; crysts (from chlfr), mp 187°; insol in w; solv in chlfr ca 20% at 25°. It can be prep'd by refluxing diphenylcarbamy chloride and ethylenediamine in ethanol. Heat of Combustion at Cᵥ 3479.05 kcal/mol and at Cₚ 3481.08; Heat of Formation at Cᵥ 44.73 and at Cₚ 54.0 kcal/mol. It may be suitable for use in proplasts

Refs: 1) Beil, not found 2) R. Lévy, MP 32, 309 (1950) 3) P. Tavenier & M. Lamoureaux, MP 38, 73 & 83 (1956)

Ethylenebis(guanidine) and Derivatives

1,1′-Ethylenebis(guanidine),
CH₂-NH-CH₂-NH
[CH₂-NH-CH₂-NH₂]; NH mw 144.18, N 58.29%. It was prep'd as various salts by reacting ethylenediamine with 5-methyl-isothiourea salts (Ref 1). The dinitrate forms ndls, dec at 252°. The dipicrate dec at 284–85°


2,2′-(Ethylenebisimino)-diethanol and Derivatives

2,2′-(Ethylenebisimino)-diethanol or 2,2′-(Ethylenediimino)-diethanol,
(H₂O.CH₂—CH₂.NH.CH₂—CH₂.H₂O); mw 148.21, mp 102–3°; prep'd by reacting 2-hydroxyethyamine with a dihaloethane compd (Ref 2)

Refs: 1) Beil, not found 2) I.G. FarbenindAG, FrP 801121 (1936) & CA 31, 111 (1937)

2,2′-(Ethylenebisimino)-diethanol Dinitrate or 2,2′-(Ethanolodimino)-diethanol Dinitrate,
(NO₂O₂CH₂—CH₂.NH.CH₂—CH₂.NO₂); mw 238.20, N 11.76%(NO₂). Prep not found in open literature

2,2'-{(Ethylenebisnitroimino)}-diethanol or 2,2'-{(Ethyleneendinitroimino)}-diethanol, (HO.CH₂.CH₂.N(NO₂)₂CH₂.); mw 238.20, N 11.76% (NO₂), crystals. It was prepd by reacting ethylenediaminedinitrime (EDNA) with ethylene oxide and NaOH (Ref 2) Refs: 1) Beil, not found 2) J.R. Johnson et al, USP 2683165 (1955) & CA 49, 7590 (1955)

2,2'-{(Ethylenebisnitroimino)}-diethanol Dinitrate or 2,2'-{(Ethyleneendinitroimino)}-diethanol Dinitrate, (ONO₂.CH₂.CH₂.N(NO₂)₂CH₂.); mw 328.20, N 17.07%, OB -39.0%, crystals, mp 66.5-67.5°. It was prepd by nitration of the above 2,2'-{(Ethylenebisnitroimino)}-diethanol Refs: 1) Beil, not found 2) J.R. Johnson et al, USP 2683165 (1955) & CA 49, 7590 (1955)

(Ethylenebisimino)-dimethanol and Derivatives (Ethylenebisimino)-dimethanol or (Ethylene-dimino)-dimethanol. Same as N,N'-Dimethylol-1,2-dinitromethane, described in Vol 5, p D1351-L

(Ethylenebisnitroimino)-dimethanol or (Ethyleneendinitroimino)-dimethanol. See N,N'-Dimethylol-1,2-dinitromethane in Vol 5, p D1351-L

(Ethylenebisnitroimino)-dimethanol Dinitrate or (Ethyleneendinitroimino)-dimethanol Dinitrate. See N,N'-Dimethylol-1,2-dinitromethane Dinitrate in Vol 5, p D1351-L

(Ethylenebisimino)-imidazolidine and Derivatives (Ethylenebisimino)-imidazolidine, +CH₂.N=CH₂.CH₂.CH₂.-; mw 166.21, N 33.71%. Not found in literature Refs: 1) Beil, not found 2) CA, not found

1,1'-(Ethylenebis(3-nitroso)))-imidazolidine, +CH₂.N(=N(NO₂))N(NO₂)CH₂.CH₂.-; mw 376.25, N 14.89% (NO₂), OB -59.6%, mp 177-78° (dec). It was prepd in 96% yield by nitration of the corresponding 2-nitroimino compd Refs: 1) Beil, not found 2) A.F. McKay et al, CanJChem 29, 382-90 (1951) & CA 46, 7094 (1952)

Ethylenebisurea and Derivatives 1,1'-(Ethylenebisurea), (Ethylenebiscarbamide) or Ethylenediurea, CH₂.NH.CO.NH₂

CH₂.NH.CO.NH₂; mw 148.15, N 37.82%; colorless crystals, mp 192-94°; sol in boiling water. It was first prepd in 1861 by Volhard (Refs 1 & 2) by interaction of AgCN with ethylenediamine hydrochloride. The compd was also prepd by Davis & Blanchard (Ref 3) and then later by Bachmann et al (Ref 4). They refluxed for 3 hours urea with 60% aqueous ethylenediamine, obtr the crude product of 188° in 89% yield; recrystallization from aqueous alc raised its mp to 192-93°.

When treated with weak nitric acid it rendered the dinitrate, while strong nitric acid gave the dinitrocompd

1,1'-(Ethylenebisurea) Dinitrate, +CH₂.NH.CO.NH₂.HNO₂; mw 272.175, N 10.29% (NO₂), OB -35.3%, mp 150-51°. It was prepd by nitration of ethylenediamine with dilute nitric acid Refs: 1) Beil 4, 254 & [693] 2) J. Volhard, Ann 119, 394 (1861) 3) T.L. Davis & K.C. Blanchard, JACS 51, 1790 (1929) & CA 23, 3442 (1929) 4) W.E. Bachmann et al, JACS 72, 3133 (1950) & CA 44, 10656 (1950) (Parent and dinitrate)

1,1'-(Ethylenebis(3-nitroso)) or 3,3'-Dinitro-1,1'-ethylenebisurea, CH₂.NH.CO.NH.NO₂

CH₂.NH.CO.NH.NO₂; mw 238.14, N 35.27%, OB -40.3%, colorless ndls, mp 197-98° (dec). It was first prepd during WWII by workers of NDRC by nitrating ethylenediamine(urea) with strong nitric acid (Ref 2). Bachmann et al (Ref 3) prepd it by dissolving 1.46g of ethylenediamine(urea) in 3.6ml of 98% nitric acid, precooled to 0°, followed (after deposition of ppt) by damping it in ice water. After allowing to stand for 15 mins, the ppt was filtered off and purified. The yield was 0.67g. The compd may also be prepd by damping in concd sulfuric acid at -5° the dinitrate of ethylenediamine(urea)

Its exp props were not reported, but its heat of combstn is given in Ref 2 as 540.4kcal/mol Refs: 1) Beil, not found 2) A.H. Blatt & F.C. Whitmore, ORSD Rep 1085 (1942), p 34 3) W.E. Bachmann et al, JACS 72, 3133-34 (1950) & CA 44, 10656 (1950)
Ethylenebisurethane and Derivatives

Ethylenebisurethane, Ethylene-(1,2-diurethane) or Junitane, $\text{CH}_2\text{NH.CO}_2\text{Et}_2$; mw 204.23, N 13.72%; ndls, mp 112°, sol in alc & eth. It was prepd by reacting ethylenediamine with ethyl chlorofomate and vacuum distillation purification. Its heat of combstn is 1066 kcal/mol & heat of formation 231 kcal/mol at const vol.

It was used in some French propants


Ethylenebisurethane-1-Azide; Ethylene-(1,2-diurethane)-1-Azide or 1-Azidoethylene-diurethane, $\text{CH}_2\text{N(N}_3\text{)}\text{NH.CO}_2\text{Et}$; mw 245.24, N 28.56%; dark yel oil, changes to another material on storage.

It was prepd by boiling azido succinylazide with alc.

Refs: 1) Beil 4, (450) 2) T. Curtius, Ber 45, 1056, 1092 (1912)

Ethylenebromide. See Ethylenedibromide in this Vol.

Ethylenebromohydrine. See 2-Bromoethanol in Vol 2, p B311-R

Ethylene Chloride or Vinyl Chloride. See Chloroethylene in Vol 3 of Encycl, p C255-R. Its 1-Nitro compd and Polymer of 1-Nitro compd are described on p C256-L

Ethylene Chlorohydrin. See Chloroethanol or Chloro Ethyl Alcohol in Vol 3, p C254. Its Nitrite, Nitrate, 2-Nitro- and 2-Nitro-nitrate-derivs are described on p C255

Ethylene Cyanohydrin or β-Hydroxypropio-nitrite, HO.CH$_2$.CH$_2$.CN; mw 71.08, N 19.71%; poisonous straw-colored liq, sp gr 1.0404 at 25°/4, fr p -46°, bp 227–28°(dec), vapor pressure 20mm at 117; miscible with w, acet, ethanol, chlf, medly-ethyl ketone; sl sol in eth; insol in benz, CCl$_4$ & naphtha. It can be prepd by interaction of ethylene oxide with hydrocyanic acid. It is used as solvent for certain cellulose esters and inorganic salts


ETHYLENEDIAMINE AND DERIVATIVES

Ethylene diamine ("en"), 1,2-Diaminoethane, H$_2$N.CH$_2$.CH$_2$.NH$_2$; mw 60.10, N 46.61%; colorless, volatile liq; strongly basic; sp gr 0.8995 at 20/20°, mp 8.5°, bp 116–17°, uD 1.4540 at 20°, vapor press 10.7 mm at 20°, viscosity 0.0154 poises at 25°, dielectric const 16.0 at 18°, fl p 43°(110°F), heat of combstn 452.6 kcal/mole, latent heat of fusion 77 kcal/g at 0°, latent heat of vaporization 167 kcal/g (calcld); very sol in w & alc; sl sol in eth; insol in benz; causes severe eye and skin burns

Typical specifications for commercial product: purity - not less than 66% by wt; boiling range at 760mm - below 115° none and above 122° none; odor - mildly ammoniacal and color - water-white

It can be prepd by heating ethylenedichloride and ammonia with subsequent distillation; purified by redistillation.

It is remarkable for its ability to take part in the formation of coordination compds, such as ammines (See Vol 1 of Encycl, pp A275ff); some of these compds are expl, as, for example, copper complexes described here under "Ethylenediamine Complexes". On neutralization with nitric acid it forms the expl Ethylenediamine Dinitrate (See below), while under other conditions it gives the expl Ethylenedinitramine, which, however, is usually prepd by nitrating ethyleneurea. Other expl compds, such as Dichlorure, Diperchlorate are prepd from ethylenediamine.

Ethylenediamine, as such, is used as a solvent for various compds, as a corrosion inhibitor in antifreeze soln, stabilizer in rubber latex, etc. Its use as a colorimetric reagent for expls, such as TNT, etc, is discussed in Vol 3 of Encycl, p C406-L

Refs: 1) Beil 4, 230, (398), [676] & [1478] 2) W.E. Bachmann, OSRD 152 or PBA 31100 (1941) (Prepn of expls from ethylenediamine) 3) A. Robertson, JSCI 67, 221 (1948) (Thermal decomp of ethylenediamine) 4) GerPat Appl No F8313 (124, 1/01), translation Res-InfoServRepr 96013, Feb 9, 1952 & April

Ethylenediamine Chlorate. See Ethylenediamine Dichlorate

Ethylenediamine-Chromium Tetroxide,
H₂N.CH₂.CH₂.NH₂+CrO₄+2H₂O; greenish-grey crystals, mp -> decmp with evoln of water and deflagration; nearly insol in w; is stable in the dark. It can be prepd from ethylenediamine, chromic acid and 30% hydrogen peroxide Re/s: 1) Beil 4, 232 2) K.A. Hofmann, Ber 39, 3182 (1906)

ETHYLENEDIAMINE COMPLEXES

Most complexes described in the literature are those of copper, but there are also complexes of cobalt, such as:
Cobalt (III) Dichloro-bis-ethylenediamino Chlorate, [Co(en)₂Cl₂]ClO₃; Cobalt (III) Dichloro-bis-ethylenediamino Perchlorate, [Co(en)₂Cl₂]ClO₄; Cobalt (III) Tris-ethylenediamino Trinitrate, [Co(en)₃](NO₃)₃

The following "en" copper complexes were prepd by Morgan & Burstall (Re/s 1 & 2)

Bis-ethylenediaminocupric Persulfate,
[Cu(en)₂]S₂O₈; purple-red acicular crystals; mp -> explodes on heating in air or while in concd sulfuric acid soln; it is unstable; detonates readily on percussion; sparingly sol in cold w, more readily in warm water. It can be prepd by addingaqK persulfate (1 mole) to anaq soln of Cu sulfate (1 mole), contg "en" (2 moles). Its expl props are comparable with those of Tetra-aquoethylenediaminocupric Persulfate (Re/fs 2 & 3)

Tetra-aquoethylenediaminocupric Perchlorate,
[Cu(en)₄][ClO₄]₂; dark bluish-violet ndls; mp -> decmp quietly; explodes violently when heated with oxidizing agents; slightly hygroscopic but stable in air; sol in w; insol in alc and most org solvents. It can be prepd by concentrating anaq soln of ethylenediamine (1 mole) with cupric perchlorate (1 mole) (Re/fs 1 & 2).

Amiel (Ref 3) prepd several expl "en" complexes by the action of a 75%aq soln of "en" on CuX₂.6H₂O, where X=ClO₃, ClO₄ or NO₃; as the reaction is exothermic, it must be conducted cautiously with cooling to avoid expls.

The compds of Amiel listed below were deliquescent, bluish-purple crystals sol in w, sol in alc and insol in alc or ether.

Chlorates: Cu(ClO₃)₂.2en.H₂O and Cu(ClO₄)₂.3en.H₂O; expl at 174° and 178°, respectively; both also explode on impact and on contact with concd sulfuric acid

Nitrites: Cu(NO₃)₂.2en and Cu(NO₃)₂.3en.H₂O; expl at 264° and 292°, respectively

Perchlorates: Cu(ClO₄)₂.2en.H₂O and Cu(ClO₄)₂.3en.H₂O; expl at 264° & 292°, respectively, as well as by impact (Ref 3a).

Of the above three complexes, the chlorates proved to be the most powerful and were recommended for use in primary compds.

Cirulis & Straumanis (Ref 4) prep'd the expl:

Ethylenediaminodiazido-copper(II), [Cu(en)(N₃)₂] or [(N₃)₂Cu(en)]; dark green ndls, mp 175–77°; expl mildly at 210° (on preheated block) or by impact of 1 kg weight (25cm); burns in flame with crepitation; sol in w; insol in alc or eth. It can be prepd by addn of Copper Azide to an amine soln.


Ethylenediamine Dichlorate. See Vol 2, p C188-R, under CHLORATES

Ethylenediamine-Diethylenetriamine Complexes. The literature contains numerous refs to the expl nature of certain coordination compds. Evidence demonstrates that metal compds contg a) coordinated ammonia & related N-contg donor molecules and b) coordinated and/or ionic groups of an oxidz nature such as perchlorate, chromate, nitrate, nitrite (or nitrate- & nitro-groups) will expl violently under various conditions. For this reason, due caution should be exercised in the prep, handling and storage of compd defined above.

Tomlinson et al (Ref 2) detd the expl props of many metal ammines and found tris-Ethylen-
diamine Cobalt (III) Nitrate & bis-Diethylene-triamine Cobalt (III) Perchlorate, among others, are expl in nature. These comds & other oxygenated compds, particularly those which are "oxygen balanced" should be considered exceedingly dangerous.


**Ethylene diamine Dinitrate (EDD or EDAD)**

(Ger DIAMIN), (Designated by Franchimont as NEDA), \( \text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{NH}_2 - 2\text{HNO}_3 \) or \( \text{O}_8\text{N}^+ - \text{CH}_2 - \text{CH}_2 - \text{NH}_3^+ - \text{NO}_3^- \); mw 186.13, N 30.10%, OB to \( \text{CO}_2 \) 25.8%; wh crystals, sp gr 1.595 at 25/4°, mp 185-87°, sol in w, insol in alc or eth. It can be prepd by neutralization of ethylene diamine dihydride with concd nitric acid, followed by concn and crystallization of salt. It forms eutectics with AN, but is immiscible with molten TNT.

Its properties are as follows (Refs 2a, 3, 6, 7, 7a, 8 & 9):

- **Brisance** – lower than for TNT
- **Combustion Test (French)** – ignites by open flame after 1 min and continues to bum at the rate of 1.5cm/min
- **Detonation Velocity (by Dauthriche Method):** 4650m/sec at sp gr 1.00, 6270 at 1.33 and 6915 at 1.50
- **Gap Test** – 3.75cm between paper cartridges each contg 50g sample at density 0.75
- **Heat of Combustion** – 374.7kcal/mole (Ref 4a)
- **Heat of Explosion** – 127.9/159.3kcal/mole
- **Heat of Formation** – 156.1kcal/mole
- **Hygroscopicity** at 25° and 90% RH – gained 1.24%
- **Ignition Temperature (French Test)** – ignites in 6 secs, when a small sample in test tube was plunged into a bath preheated to 370°; the time was 1 sec, when the temp in the bath was 430°
- **Impact Sensitivity** – less sensitive than PA and TNT; FI 120% PA. French test with 10kg weight (mouton) gave at the height of drop 2.50 meters, 50% detonations
- **Initiation Sensitivity** – 50g sample pressed to sp gr 1.22 in a paper cylinder 30mm diam required 2g MF for its detonation
- **Power (Strength)** – sl more powerful than TNT, but less powerful than EDNA. Ballistic Mortar Test – 114% TNT. Trauzl Lead Block Test – 115% PA or 120-125% TNT
- **Rifle Bullet Test** was dtd by Méard & Cessar (Ref 7a) for charges of sp gr 1.0 – no detonations on impact of bullets with velocities below 960m/sec and incomplete deton is for velocities around 1000m/sec

**Sensitivity to Impact.** See Impact Sensitivity

**Sensitivity to Initiation.** See Initiation Sensitivity

**Thermal Stability** – decomp with formation of brown fumes at 270°; does not expl at 360°

**Thermal Stability at 135°.** Accdg to Blatt (Ref 2a), it does not become acid and does not expl in 300mins

**Uses** – used by Germans during WWII as pressed charges in shells and as cast charges in eutectic mixts with AN. In mixts with wax it was used in boosters (Refs 3 & 10)

**UV Spectra** were dtd in Canada (Ref 7)

**Velocity of Detonation.** See Detonation Velocity

Ethylene diamine Dinitrate was manufd in Germany, under the name of DIAMIN, from synthetic raw materials: ethanol, ammonia and nitric acid (Ref 3)

Its uses during WWII by the Germans are indicated above under Uses.

Two of its German eutectic mixtures were investigated at PicArsn (Ref 3). They were: 1) EDD 45 & AN 55% and 2) EDD 45, AN 53.5 & Al 1.5%

Their props were approximately as follows:

- **Ballistic Strength** 126% TNT; **Brisance** – less than for TNT; **Decomposition Temperature** – 278°C; **Detonation Velocity** – less than for EDD; **Impact Sensitivity** – similar to that of EDD; **Reaction with Metals** – similar to that with Amatols (See Vol 1 of Encycl, p A161-R)

Fichesroufle (Ref 6), proposed a mixture with favorable OB to \( \text{CO}_2 \) consisting of EDD 42.8 & AN 57.2% and designated as NB79.

Its props are in comparison with **Schneiderite** (DNN 87–88 & AN 13–12%)

- **Detonation Velocity** – 6183m/s at d 1.35 (Sch 5723);
- **Gap Test** – 7.75cm betw two paper cartridges contg 50g sample at d 0.94 (Sch 6.5cm);
- **Impact Test with 5kg Weight** – slightly more sensitive than Sch;
Initiation Sensitivity — 0.20g MF for sample at d 0.94; Power by CUP (Modified Trauzl Test) — 113.5% PA (Sch 113%); Stability at 100° — tumb litmus paper red in 43.5 hrs (Sch 28.75 hrs). Although its expi props and stability are slightly more favorable than those of Schneiderite, it is not recommended by Fichetolle as a bursting chge of projectiles in lieu of Schneiderite due to its higher cost.

LeRoux (Ref 8) recommended eutectics EDD/AN for use in shell-loading replacing Amatols.

LeRoux (Ref 9) prepd a binary 50/50 eutectic of mp 100° by mixing dry powdered ingredients, followed by heating the ensemble to 105°, with stirring, and then cooling. For the sake of comparison a 50/50-Amatol was prepd by heating TNT to 120° and adding to it, with stirring powdered AN. The EDD/AN was designated as Mixture I, while Amatol was Mixture II: Detonation Velocity — 5990m/sec at sp gr 1.62 for I, vs 6150 at 1.60 for II; Impact Sensitivity with 10kg wt — 50% detonation at the height of 2m for I & II; Initiation Sensitivity — 50g mixt I of sp gr 1.0 required 0.5g MF for deton, vs 0.3g MF for mixt II; Power by Coeffient d’Utilisation Pratique (CUP) Method, described in Vol 1, p IX — 116% PA for I, vs 112% for II; Riffe Bullet Test at sp gr 0.90 of material packed in boxes: Mixture I detond by bullet of velocity 510m/sec and up, while II detond at 500m/sec and up. 

Refs: 1) Beil 4, 484; 2) G.C. Hale, USP 2011578 (1935) & CA 29, 6762 (1935) (Prepn & props) 2a) Blatt, OSRD 2014 (1944) (Prepn & props) 3) Allied & Enemy Explosives (1946), p 145 (Prepn, props and uses) 4) A.N. Campbell & J.R. Campbell, Can J Res 25B, 96 (1947) (Some props) 4a) ADL Pure Expl Compds, Pt 2 (1947), p 237 5) A.J. Robertson, JSCI 67, 221—24 (1948) & CA 43, 405 (1949) (Thermal decomp of EDDAD) 6) H. Ficherouille, MP 30, 89—100 (1948) (Prepn, props and mixts with AN) & CA 45, 8249 (1951) 7) R.N. Jones & G.D. Thom, Canad J Res 27B, 830 & 855 (1949) (UV Spectra) & CA 44, 2848 (1950) 7a) L. Ménard & M. Cessat, MAF 23, 195 (1949) 7b) ADL Synthesis HE’s, 1st Report (1949), p 165 8) A. LeRoux, MP 32, 121—31 (1950) & CA 47, 9014 (1953) (Explosion and of its mixts with AN meltg around 100°, which were found to be suitable for cast-loading as bursting charges of shells in lieu of Amatols) 9) A. LeRoux, MP 34, 141 & 146 (1952) (Properties of 50/50-EDD/AN are listed in comparison with those of 50/50-Amatol) 10) Fedoroff et al, PATR 2510 (1958), pp Ger 35-R, 47-L & 48-L. [Forms eutectics: 45/55-EDD/AN and 45/55.5/1.5-EDD/AN/Al, of which the 2nd mixt was used under the name Füller (Filier) No 20 in lieu of Ammonal. The mixture 55/45-EDD/AN, known as Füller 84 was used for cast-loading some shells] 


Ethylenediamine-Dinitroform Salt, CH₂.NH₂.HC(NO₂)₃; mw 362.18, N 30.94%; OB to CO₂ = 4.4%, yel crys, mp 199°(dec), impact sensitivity 28—30 cm with 2kg wt. This compd was prepd in the USA after WWII (Ref 3). It is an expl with heat of combustion 1830 cal/g at const vol with water liq; and ballistic mortar value 149% TNT. The props describing its prepn & other props are listed in Ref 2a.

It is reported that an aq soln of ethylenediamine (1 mol) + nitroform (2 mols) yielded the yel dinitroform salt, mp 118° (Ref 2a, p 59) 

Ref: 1) Beil, not found 2) CA, not found 2a) K. Klager & M.B. Frankel, Aerolab Special Rep 494 (1951), 14, 59 & BIOS/Gr-2 HEC No 5475 3) Dr W.L. Gilliland, Purdue Univ, Lafayette, Indiana 4) ADL 2nd Rep on Synth & Testing of HE’s (1951), pp 33, 304, 312, 328, 346 & 374

Ethylenediamine Diperchlorate, (CH₂.NH₂)₂.2HClO₄; mw 281.01, N 9.97%, OB = 6.1%; hygroscopic crys. It can be prepd by reaction of the diamine with Ammonium Perchlorate. Power by Ballistic Mortar 135% TNT; Power by Trauzl Test 144%; Sensitivity to Impact FI > PETN. 

Refs: 1) Beil 4, 399 & 4841 2) A.H. Blatt & F.C. Whitmore, OSRD 1085 (1942), 34 3) A.H. Blatt, OSRD 2014 (1944) 4) W.W. Vogl, USP 2406753 (1946) & CA 41,
Ethylenediamine Dipipate. See 1,2-Bis-(2',4',6'-trinitroanilino)-ethane in Vol 2, p B131-R

Ethylene-N,N'-dinitramine Dipipate. See 1,2-Bis(2',4',6'-trinitromethylanilino)-ethane in Vol 2, p B131-R and Ditetral or Ditetrel in Vol 5, p D1513-L

Ethylenediaminetetraacetic Acid (EDTA) \( (\text{HOOC.CH}_2\text{NH.CH}_2\text{CH}_2\text{NH.CH}_2\text{COOH})_2 \). One of the most important chelating agents (See under Chelation in Vol 2, p C164-R), mw 292.24; colorless crysts, mp = decom pt at 240°; s soluble in w; insol in common org solvents; neutralized by alkali metal hydroxides to form a series of w-sol salts contg from one to four alkali metal cations. It can be prepd by the addn of NaCN and formaldehyde to a basic soln of ethylenediamine to form the tetrasodium salt. Another method is by heating tetrathydroxyethylidiamine with Na or K hydroxide, using a CdO catalyst, to form the tetrasodium salt (Ref 4, p 465-R)

It forms numerous salts, some of which are listed in Ref 4, p 466-L. It has been used for determination of about 40 metals and several anions (Ref 2); also used for decontamination of radioactive surfaces and removal of insol deposits of Ca & Mg soaps (Ref 4). Its application in volumetric titrations is discussed in Ref 3. Accdg to Arose Chem Co, PO Box 1294, Providence, RI, EDTA dissolves Ca oxalate and serves as a sequestrene. The term sequestration may be used for any instance in which an ion is prevented from exhibiting its usual props due to close combination with an added material (Ref 4, p 1013-L)


Ethylenediamine-Trinitromethane. See Ethylenediamine-Dinitroform Salt in this Vol

Ethylenediamine, Mononitro, N-Nitroethylenediamine, or &-Aminoethylenenitramine, H\(_2\)N.CH\(_2\).CH\(_2\).NH.NO\(_2\); mw 105.10, N 39.98%; wh crysts, mp 240°, 244.8° (Ref 2). It was prepd by reaction of CICH\(_2\).CH\(_2\).N-(OPr)-NH.NO\(_2\) with 10% KOH-ethanol (Ref 2), or by refluxing in water 1-nitro-2-nitriminoimidazolidine (Ref 3)


Ethylenediamine, N,N'-Dinitro, ETHYLENEDINITRAMINE, EDNA, Haleite or 1,2-Dinitrodiaminothane. (The name Haleite is in recognition of its development as a military explosive by the late Dr G.C. Hale of Picatinny Arsenal), O\(_2\)N.HN-CH\(_2\).CH\(_2\).NH.NO\(_2\); mw 150.10, N 37.33%, OB to CO\(_2\) -32%; OB to CO -10.5%; wh orthorhombic crysts; sp gr 1.71 (crysts); density = 1.39 for pressed at 10000psi; 1.49 at 20000 and 1.56 at 40000psi; mp 177-79° (starts to decompose at 175°)

Solubilities in 100g of Solvent:
Water: 0.25g at 20°; 0.75 at 40°; 2.13 at 60°; 6.38 at 80° and > 20 at 100°
Alcohol: 1.00g at 20°; 2.46 at 40°; 5.19 at 60° and 10.4 at 78°
Ether, chloroform and benzene – very sl sol

It was first prepd in 1888 by Franchimont (Refts 1 & 2), but its value as a military expl was not recognized until Dr Hale prepd and examined it at Picatinny Arsenal (Ref 3)
The earliest method used at PicArns was in 1933. It consisted of treating ethylenediamine with diethylcarbonate to obtain ethyleneurea, followed by nitration to obtain Dinitroethyleneurea, which on hydrolysis gave Ethylenedinitramine. This process suffered from two disadvantages: the overall yield was only 42% of the theoretical amt; and the initial step, the reaction between ethylenediamine and diethylcarbonate, required the use of high pressures and temperatures over an extended period of time. However, the expl props of EDNA were of sufficient interest to justify further study (Ref 4). See also Aaronson (Ref 5)

With this background, Division 8 of NDRC began work in the fall of 1940 on the synthesis of EDNA that would avoid the unsatisfactory reaction betw ethylenediamine
and diethylcarbonate. Two approaches were investigated: the 1st was a synthesis which did not involve ethyleneurea as an intermediate; the 2nd was an improved synthesis of ethyleneurea (Ref 11).

Laboratory studies developed several methods from which was selected the method of using cheap and available raw materials. When in this synthesis nitration was done with concd nitric acid alone (instead of mixed acid), the overall yield of EDNA was 70% of theoretical and its cost was 30 cents per pound which was considered reasonable.

The reactions proceeded as follows:

\[
\begin{align*}
\text{CH}_2\text{O} + \text{HCN} + \text{HOCH}_2\text{CN} & \rightarrow \text{H}_2\text{NCH}_2\text{CNH}_2 + \text{H}_2\text{O} \\
\text{(98% yield)} & \quad \text{(82% yield)} \\
\text{at high pressure} & \\
\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 & \rightarrow \text{CO}_2 \\
\text{at 220°} & \quad \text{820 atm press} \\
\text{CH}_2\text{CNH}_2 \text{CO} + \text{H}_2\text{O} & \rightarrow \text{CH}_2\text{CN}_{2}\text{NO}_2 \quad \text{(98%)} \\
\text{CH}_2\text{CNH}_2 \text{CO} + 2\text{H}_2\text{O} & \rightarrow \text{CH}_2\text{CN}_{2}\text{NO}_2 \\
\text{Hydrolysis} & \quad \text{CH}_2\text{CNH}_2 \text{NO}_2 \\
\text{at 95°} & \quad \text{CH}_2\text{CNH}_2 \text{NO}_2}
\end{align*}
\]

(Ref 11, pp 13 & 14 and Ref 22, pp 153–54)

Fichonolle (Ref 13, p 89) stated that EDNA can be prepared either by boiling in water Dinitroethyleneurea or by treating Dinitroethylenediamine with an alcoholic soln of ammonia, followed by acidifying with HCl.

\[
\begin{align*}
\text{CH}_2\text{N}_2\text{COOC}_2\text{H}_5 \quad \text{CH}_2\text{N}_2\text{COOC}_2\text{H}_5 & \rightarrow \text{CH}_2\text{N}_2\text{H}_2\text{NH}_2 \\
\text{NH}_3 & \quad \text{HCl} \\
\text{CH}_2\text{N}_2\text{COOC}_2\text{H}_5 \quad \text{CH}_2\text{N}_2\text{COOC}_2\text{H}_5 & \rightarrow \text{CH}_2\text{N}_2\text{H}_2\text{NH}_2 \\
\text{HCl} & \quad \text{HCl} \\
\text{Dinitroethylene-} \quad \text{Dinitroethylene-} &
\end{align*}
\]

Bachmann et al (Ref 17) investigated possibilities of prep of EDNA from the following dinitro compounds: 1,3-Dinitro-2-imidazolidone; Dinitroethyleneisothiourea; N,N' Dinitroethylenebisacetamide; N,N' Dinitroethyleneoximide and 3,3'-Dinitro-1,1'-ethylenebisurea, and he found that EDNA could be obt from any of these compds with the exception of the 3,3'-Dinitro-1,1'-ethylenebisurea.

EDNA is an explosive combining the props of an HE like TNT and an initiating agent like MF or LA. It possesses an advantage of combining a high brisance with comparatively low sensitivity. Usually it is recognized that a HE possessing a very high brisance (e.g. PETN, RDX or NG) is more sensitive to impact, friction or initiation than the less brisant expls, such as TNT. Another important characteristic of EDNA is its relatively low explosion temp, approaching that of MF or NG. No other HE is known which has such a low sensitivity to impact and at the same time so readily explodes by heat.

As EDNA lacks oxygen for complete combustion to CO₂, it may be used in mixts of inexpensive oxidizing agents such as AN, K chlorate, Amm perchlorate, etc, giving a series of expl mixts which are more powerful than EDNA.

Properties of EDNA:

- **Booster Sensitivity** — minimum total wt of two Tetryl pellets, which produced 50% detons of EDNA of density 1.42 confined in a cartridge 1-5/8 inches diam by 5 inches long, separated from Tetryl by Acrowax B spacer 1-5/8 inches diam and 2.09 inches thick was 100g (22, p 151)
- **Brisance by Plate Cutting Test** - equivalent to PETN (Ref 7a)
- **Brisance by Plate Denting Test** - 122% TNT for pressed, confined EDNA at 1.50X(22, p 150)
- **Brisance by Sand Test** - 52.3g sand crushed vs 48g for TNT (109%)

Compatibility with Metals (Ref 22, p152)

Unaffected dry: Cu, brass, Al, mild steel, stainless steel, Ni, Cd and Zn

Unaffected wet: stainless steel

Slightly affected dry: Mg & Mg-Al alloy

Heavily corroded wet: Cu, brass, mild steel, Cd, Ni and Zn

Decomposition Equation. The kinetics of compn of EDNA were studied over the temp range 144.4 t o 163.5°C. At the higher temp the sample darkened to a red bm with evolution of NO₂. At lower temp only sl decomp was observed. The true decomp rate is first order. The data followed the Arrhenius equation and are tabulated (Ref 20b).

Decomposition Temperatures: 170° in 20 seconds; 173° in 15 secs; 178° in 10 sec; and 189° in 5 secs

Destruction by Chemical Decomposition. EDNA is decomp by addn of hot, dilute
sulfuric acid with evolution of nitrous oxide and ethylene glycol. It can also be decomposed by addition to 5 times wt of 20% Na hydroxide (Ref 22, p 154).

**Detonation Velocity** - 7570 m/sec for pressurized unconfined sample 1.0 inch diam of density 1.49 (Ref 22, p 150); Blatt (Ref 7a) gave 7580 for sample of d 1.50 and 5650 for d 1.0; Ficheronelle (Ref 13) gave 6600 for d 1.25 and 7137 for d 1.50. *Explosion Temperature*: 0.1 sec (no cap used) 265°C 1 sec 269°C (Ref 22, p 150) Blatt (Ref 7a) gave 205°C in 1 sec *Exudation* - none (Ref 22, p 152) *Flammability Index* - 138 seconds. Its definition is given in this Vol, under F's *Fragmentation Test*: Sample of 95/5 EDNA/WAX of d 1.56 detonated in 3 inch HE, M42A Projectile produced 600 fragments vs 514 for TNT (Ref 22, p 152). *Friction Pendulum Test*: unaffected by fiber or steel shoe (Ref 22, p 150).

**Gap Test** (Fr: Transmission de la détonation à l'aire libre): 14cm distance between two paper cartridges, each containing 50g EDNA of density 0.80, vs 22cm for Tetryl of d 0.94 (Ref 13) *Gas Volume* - 908 cc/g (Ref 22, p 151) *Heat of Combustion* - 2477 cal/g (Ref 22, p 151); 369.7 kcal/mole (Ref 7a) *Heat of Explosion* - 1276 cal/g (Ref 22, p 151) *Heat of Formation* - 134 cal/g (Ref 22, p 151).

**Heat Test at 100°C** (Fr) - limus paper turns red after 48 hours of exposure, vs 3.30 hrs for Ethylenediamine Dinitrate (Ref 13) *Heat Test at 100°C (US)* - % loss in 1st 48 hrs 0.2, in 2nd 48 hrs 0.3 and no expln in 100 hrs (Ref 22, p 150) *Heat Test at 135°C* - satisfactory *Hygroscopicity* - 0.01% gain at 90% RH (Ref 22, p 150) *Impact Sensitivity*, 2 kg wt - 48cm with BurMines App vs 100cm for TNT, for 20 mg sample or 14 inches with PicArsn App for 17 mg sample (Ref 22, p 150) *Impact Sensitivity (Bradt)* - Fl 61% PA (Ref 7a) *Impact Sensitivity (Fr)* (Sensibilité au choc) using 5kg wt app EDNA produced 38 detonations out of 100 trials at the height of 1.50 meters, vs 70 detonations for Ethylenediamine Dinitrate and 95 detonations for Tetryl (Ref 13) *Initiation Sensitivity to - minimum detonating charge 0.21g MF or 0.13g LA (Ref 22, p 150) 0.20g MF for EDNA at d 0.8 (Ref 13) *International Heat Test at 75°C* - % loss in 48 hrs - 0.01 (Ref 22, p 150) *Loading Densities* - 1.49, when pressurized at 20000 psi, 1.28 at 5000; 1.38 at 10000; 1.41 at 12000 and 1.44 at 15000 (Ref 22, p 152) *Power by Ballistic Mortar* - 136% TNT (Ref 7a); 139% TNT (Ref 22, p 150) *Power by Trauzl Test* - 118% PA (Ref 7a); 122% TNT (Ref 22, p 150) *Power by Modified Trauzl Test* [Fr Coefficient d'Utilisation Pratique (CUP), described in Vol 1, p IX] - 129% PA (Ref 13) *Rifle Bullet Impact Test* - Similar to TNT, but less sensitive than RDX (Ref 7a); in 100 trials there were 60 partial detonations, 20 burnings and 20 unaffected (Ref 22, p 150) *Sand Test*. See under Brisance by Sand Test *Sensitivity to Impact*. See Impact Sensitivity to Initiation. See Sensitivity to Initiation *Stability at 135°C*. See Heat Test at 135°C *Schrage* - dry (Ref 22, p 152) *Surveyance* - slight lowering of mp, but no increase in stability after storage for 4 months at 65°C (Ref 7a) *Thermal Stability at 135°C*. See Heat Test at 135°C *Uses*. See below *UV Spectra*. See Ref 15

**Vacuum Stability Tests**: at 100°C - 0.5 cc/5g in 48 hrs; at 120°C - 1.5cc and 135°C 11+cc (Ref 22, p 150); at 120°C - 2.4cc/5g in 48hrs (Ref 7a) *Velocity of Detonation* - See Detonation Velocity *Vapor Pressure* - nil (Ref 22, p 15) *Uses*: It was proposed as a pressurized charge in booster both in USA (Ref 22, p 152) and in France by Ficheronelle (Ref 13). He also proposed a mixture of EDNA 38.5 & AN 61.5%, which he designated as NBB; it was more powerful than EDNA, still less stable, had gap test value 11cm and deton velocity 8600m/sec at d 1.60 *Refs for EDNA*: 1) Beil 4, 572 & (569) 2) A.P.L. Franchimont & E.A.Klobbie, RecTrav Chim 7, 17 & 244 (1888); 3) A.P.L. Franchimont, Rec 29, 308 (1910); 4) G.C. Hale, USP 2011578 (1935) & CA 29, 6762 (1935) 5) H.A. Aaronson, USP 2149260 (1939) & CA 33, 4273 (1939) 6) W.E. Bachmann, OSRD 819 & PBA 31199 (1942) (EDNA and related

**Addl Refs for EDNA:**

A) Thorpe 4(1940), 489 (Prepn & props of EDNA)  
B) J.D. Hopper, PATR 1113(1941) & 1162(1942) (Study of manuf of EDNA on a semiplant scale)  
C) H.A. Aaronson, PATR 1198 (1942) (Stability of EDNA and its mixts with TNT)  
D) H.A. Aaronson, PATR 1199 (1942) (Development of assay method for EDNA)  
E) H.A. Aaronson, PATR 1200 (1942) (Development of assay method for EDNA)  
F) H.A. Aaronson, PATR 1232 (1943) (Development of assay method for Ethyleneurea)  
G) W.R. Tomlinson, PATR 1252 (1943) (Study of rates of hydrolysis of Dinitroethyleneurea & EDNA)  
H) A.L. Sandifer, PATR 1279 (1943) (Study of manuf of EDNA on a semi-plant scale)  
I) H.A. Aaronson, PATR 1288 (1943) (Study of manuf of EDNA on a semi-plant scale)  
J) H.A. Aaronson, PATR 1294 (1943) (Stability of EDNA and its mixts with TNT)  
K) J. Rubin, PATR 1319 (1943) (Manuf of EDNA on a semi-plant scale)  
L) Clift & Fedoroff, Vol 1 (1943), p E3 (Ethylene-dinitrimine or N,$^\mathrm{N}$-Di-dinitromethyleneamine)  
M) J. Rubin, PATR 1378 (1944) (Props of Ammonium Salt of Haleite)  
N) H Aaronson, PATR 1395 (1944) (Stability
of EDNA and its mixts with TNT)
O) D.R. Cameron, PATR 1400(1944) (Fragmentation tests of 37mm M36 and 105mm M38A1 Shell loaded with Haleite, Ednatol and other explosives)
P) S. Sage, PATR 1434(1944) (Properties and military characteristics of Haleite & Ednatol)
Q) H. Aaronson, PATR 1600(1946) (Preparation & props of nitrated condensation product of Haleite, formaldehyde and ammonia)
R) F. Pristera, PATR 1796(1951) (A method for staining Cyclotols, Ednatols, Pentolites and Picratols for observing and studying non-TNT phase)
S) S.M. Kaye, PATR 1937(1953) (Determination of purity of EDNA by titration in nonaqueous medium)

Ethylene nitramine (EDNA or Haleite). Specification Requirements and Tests
Applicable Specification: PXS–1033 (Rev 2), 24 July 1943 and Amend 1, 7 April 1947

Specification Requirements:
1. Moisture — 0.10% (max)
2. Color — white to buff
3. Melting Point — 174°C (min)
4. Purity — 99.0% (min)
5. Insoluble Matter — 0.10% (max)
6. Granulation:
   Thru US Std Sieve No 10 — 100% (min)
   Thru US Std Sieve No 100 — 20% (max)
7. Grit — none

Laboratory Tests:
1. Moisture. Transfer a portion of approx 5g of the sample to a tared weighing dish of at least 1.5 inches diameter, and weigh. Place the dish in a vacuum desiccator containing sulfuric acid and evacuate to a pressure not greater than 150mm of Hg. After 30 mins, remove the dish, and re-weigh. Calculate any loss in wt to percentage of moisture in the sample
2. Color. Determine by visual examination
3. Melting Point
   A. Apparatus. Set up a melting point bath equipped with a mechanical stirrer and a source of heat that can be easily regulated. A beaker of 1 to 2 liters capacity about ¾ full of clear peanut oil is recommended. Suspend an accurately standardized total immersion Centigrade thermometer in the bath so that the bulb is not less than 1.5 inches from the bottom of the bath. If the mercury column will not be completely immersed at the temperature of the observed melting point, suspend a second thermometer about 0.5 inch from, and with its bulb at about the height of the middle of the exposed mercury column of the first thermometer
   B. Determination. Use thin-walled capillary tubes of uniform diameter, long enough to extend beyond the top of the bath. Fill the tube with dry sample to a depth of approx 4mm, and compact the material by tapping. Start the stirrer and heat the bath rapidly to 165°C, and then at such a rate that the rise in temperature is 1.0±0.5°C in 2 minutes. When the temperature reaches 172°C, attach the melting point tube so that its lower end is in contact with the bulb of the thermometer. Continue heating so that the temperature continues to rise at the same rate. Consider the uncorrected melting point to be the temperature at which the solid in the tube softens and breaks up into sections which usually rise in the tube
   C. Correction. If the mercury column is completely immersed at the above temperature, report this temperature, with calibration corrections applied, as the melting point of the sample. If part of the column is exposed, add the following correction to the above temperature:
   \[ \text{Correction} = n (T-t) \times 0.000159 \]
   Where:
   \[ n = \text{Number of degrees in the exposed column} \]
   \[ T = \text{Uncorrected melting point} \]
   \[ t = \text{Average temperature of exposed mercury column} \]
4. Purity. Transfer from 1.1 to 1.2 grams of the sample to a tared weighing dish and weigh accurately. Transfer the weighed portion to a clean 500cc Erlenmeyer flask by means of distilled water and wash down the neck and walls. Use a total of 100 to 125cc of distilled water. Add 48 to 49cc of N/3 sodium hydroxide solution with constant swirling of the contents of the flask so as to hasten solution of the Haleite. Heat the flask on a hot plate until the contents are boiling and by means of distilled water, wash down any undissolved material adhering to the wall of the flask. When solution is complete, cool the flask and contents to room temperature. Add 10 drops of phenolphthalein solution (0.5g per 100cc of alcohol) and titrate with approx N/5 sulfuric acid solution until the solution is a faint pink or has become colorless. In the latter case,
titrate with a N/3 sodium hydroxide until a pink color reappears. Correct the volumes of alkali and acid to standard temperature, and calculate the purity of the sample.

Percentage purity = \( \frac{7.505 \times (AB - CD)}{E} \)

Where:
- \( A \) = cc of sodium hydroxide solution used
- \( B \) = Normality of sodium hydroxide solution
- \( C \) = cc of sulfuric acid solution used
- \( D \) = Normality of sulfuric acid used
- \( E \) = Weight of sample used

5. Insoluble Matter. Transfer a weighted portion of approximately 10g of the sample to a 250cc beaker. Add 200cc of distilled water and heat to boiling. When solution is complete, filter through a rarefied Gooch crucible. Wash the beaker and insoluble residue in the crucible thoroughly with boiling distilled water until free from soluble material. Dry the crucible and contents at 100°C for 2 hours, cool in a desiccator, and weigh. Calculate the weight of residue in the crucible to percentage of insoluble matter in the sample.

6. Granulation. Transfer a 100g portion of the sample to a No 10 US Std sieve superimposed on a No 100 US Std sieve and equipped with a bottom pan and cover. Shake the assembly for three minutes. Weigh any material retained on the sieves and calculate the percentage of the sample passing thru each sieve.

7. Grit. Transfer a 25g portion of the sample to a 1 liter beaker and add 500cc of boiling distilled water. Heat until solution is complete. Pour the solution into a No 60 US Std sieve and wash any residue on the sieve with a jet of hot distilled water. When no more insoluble material passes thru the sieve, dry the sieve and residue remaining on it. Transfer the dry residue to a piece of paper and then to a smooth glass slide. Rub the material on the glass by exerting pressure with a smooth steel spaulda blade. Note if particles of grit are present as indicated by lack of uniformity of the material and the persistence of a scratching noise when pressing and rubbing of the material on the glass is continued.


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EDNA SALTS

Ethylenediamine-N,N′-dinitro Salts with Ammonium and Metals:

Diammonium Ethylenedinitramine, (AEDNA)

\[
\begin{align*}
\text{CH}_2\text{N} & \quad \text{NO}_2 \\
\text{CH}_2\text{N} & \quad \text{NH}_4 \\
\end{align*}
\]

mw 184.17, N 45.64%, OB -52.2%; crysts, sp gr 1.505 at 18°C; mp 158°C (Ref 9), decomp at 180°C (Ref 6); sol in w; insol in absol alc or in eth. It can be prped by saturating ethylenedinitramine with ammonia, separating the crysts and purifying them; for this they are dissolved in 20% ammonia and pptd by ammoniacal abs alc, followed by pressng the crysts on a fritted glass, rinsing with ammoniacal abs alc and drying in cold over KOH.

(Drying over H_2SO_4 or CaCl_2 results in loss of some NH_3) (Ref 9). B & F (Ref 3) prped it by warming EDNA in alc with concd ammonium hydroxide.

Following are its other props (Refs 3, 5, 6 & 9)

Brisance - no info; Decomposition Temerature - 180°C with evolution of white fumes; Detonation Velocity - 7132m/sec at density 1.35; Heat of Combustion at C_V and 18°C - 519kcal/mole; Heat of Formation at C_V - 74.6kcal/mole; Hygroscopicity - very high; Impact Sensitivity with 5kg Weight - at the heights 1.0 to 1.5 meters only 2 detonations out of 100 drops; Initiation Sensitivity - detonates very difficultly at density 0.70 by means of 3g MF; Power by CUP Method (Modified Trauzl Test) - 69.5% PA vs Tetryl 120%; Stability - low

Uses: In the opinion of Ficherouffe (Ref 6), AEDNA could be useful when an expl with extremely low sensitivity is required. He proposed the following binary mixture NB78-AEDNA 27.7% & AN 72.3% with favorable OB to CO_2 and found that although its power (by CUP) is high (104.4% PA), its sensitivity to impact is too high for use as a bursting charge in shells in lieu of Schneiderite - (DNN 87-88 & AN 13-12%); and besides it is more expensive than Schneiderite.
Copper Ethylenedinitramine,

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Cu} \\
\text{CH}_2\text{N}^{\text{NO}_2} \\
\]

mw 211.62, N 13.24\% (NO₂), OB -22.6\%

Accdg to Blatt (Ref 4), its impact sensitivity is 17 cm for 50\% explns using a 5 kg wt; its FI is 30\% - 40\% PA and it ignites w/o deton at 350°

Dipotassium Ethylenedinitramine,

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{K} \\
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{K} \\
\]

mw 226.18, N 12.38\% (NO₂), OB -21.2\%, ndls (from alc). Accdg to Ref 7, the mono-K salt is amorphous, and the di-K salt is cryst but is a dihydrate when prep'd from an aq system. The di-K salt was prep'd by cooling a warmed soln of KOH, water, 95\% ethanol & EDNA

Blatt (Ref 4) gives its impact sensitivity as 43 cm vs 51 cm for RDX with 5 kg wt for 50\% explns

Disilver Ethylenedinitramine,

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Ag} \\
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Ag} \\
\]

mw 363.82, N 7.70\% (NO₂), OB -13.2\%, wh powd. It is prep'd by adding a soln of the K salt to excess AgNO₃ (Ref 1)

Disodium Ethylenedinitramine,

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Na} \\
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Na} \\
\]

mw 194.06, N 14.43\% (NO₂), OB -24.7\%. Accdg to Ref 7, the mono-Na salt is amorphous, and the di-Na salt cryst in ndls (from water); prep'd by dissolving EDNA in 10\% NaOH and pptg w alc

Iron Ethylenedinitramine

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Fe} \\
\text{CH}_2\text{N}^{\text{NO}_2} \\
\]

mw 203.93, N 27.47\%, crysts, insol in water. Its impact sensitivity is 21 cm for 50\% explns using 5 kg wt vs 51 cm for RDX in same test. It is formed by adding Pb nitrate to an aq soln of the Na compd (Ref 4)

Lead Ethylenedinitramine,

\[
\text{CH}_2\text{N}^{\text{NO}_2} \quad \text{Pb} \\
\text{CH}_2\text{N}^{\text{NO}_2} \\
\]

mw 355.27, N 7.88\% (NO₂), OB -18.0\%. Accdg to Ref 8, the Pb salt is formed by dissolving equimolar parts of EDNA in sodium hydroxide solution and then adding an equimolar part of lead nitrate solution and filtering the pptd lead salt. The salt is heat stable up to 300°C and crushes 17 g of sand in a sand bomb

Blatt (Ref 4) lists its impact sensitivity as 30 cm for 50\% explns using a 5 kg wt vs 51 cm for RDX in same test; its FI is 49\% PA and ignites at 310° in 1 sec

EDNAFIVE (Ethylendinitramine–Fivonite)

50/50 Ednafive is a castable HE composed of EDNA 50 & Fivonite (Tetramethylcyclopentanone Tetrinitrate) 50 + 1% catechol. Its power is 130% TNT by Ballistic Mortar Test and brisance by PDT (Plate Dent Test) is 111% of TNT. In the Bullet Impact Test of 15 1-inch pipe nipples, 9 samples were not affected and 6 partially exploded. A 60/40 Ednafive mix in the same latter test of 13 nipples showed 5 samples not affected, 7 exploding and 1 detonating a high order; in a welded can the test of 5 samples showed 5 partially exploding.

Fivonite alone has a PDT value of 106–112%, BMT 121–122% and Trauzl Test value 129% of TNT. Its vel of detonation is 7300m/sec at sp gr 1.57


EDNATOLS. Combinations of EDNA (Ethylendinitramine) and Tol (TNT) in various proportions. The most used mixes are EDNA/TNT–60/40, 55/45 and 50/50. They are powerful expls which melt at ca 80°C and can be cast at ca 85°C, giving yellowish uniform blends suitable as bursting charges in ammunition. These expl mixtures were developed at Picatinny Arsenal just prior to WWII. For their prepn wet EDNA was added slowly to molten TNT heated to ca 105°C in a steam jacketed melting kettle equipped with a stirrer. Heating and stirring were continued until all moisture was evaporated. Loading in ammunition was done by pouring the mixture cooled to 85°C.

Although the properties of mixts 60/40, 55/45 and 50/50 are known (as detd at PicArsn), it is sufficient to list here only the props of 55/45–Ednatol, as was done by Tomlinson & Sheffield (See Ref 2)

Properties of 55/45–EDNA/TNT Mixture

Oxid: Balance to CO₂ –51% and –17% to CO Density (cast) – 1.62gr/cc

Blast (Relative to TNT) in Air: Peak Pressure 108%, Impulse 110% and Energy 108%

Blast Under Water: Energy 113%

Booster Sensitivity Test (See Vol 1 of Encycl, p VIII), using 100g Tetryl pellet. Thickness of Acrawax B pellet to achieve 50% detona- tions was 1.28 inches

Brisance by Sand Test in 200g Bomb – 112% TNT

Brisance by Plate Test B – 112% TNT

Eutectic Temperature – ca 80°C

Explosion Temperature in 5 secs – ca 190°(dec)

in 1 sec – ca 248°(dec)

Exudation Test at 65° – no exudation

Flammability Index – Will not continue to burn

Fragmentation Test – in 3-inch M42 Shell – 118% TNT

Fragment Velocity – 2730ft/sec at 9 ft and 2430 at 25.5 ft

Friction Pendulum Test – unaffected by fiber or steel shoe

Heat Test at 100°C – % Loss in 1st 48 hrs 0.2

% Loss in 2nd 48 hrs 0.1

No expln in 100 hrs

Hygroscopicity, % Gain at 30° & 90% RH – none

Impact Sensitivity, Burrowing Test, 2kg wt, 95cm for 20mg sample

Initiation Sensitivity – Minimum detonating charge: MF 0.22–0.25g. Did not deton consistently with No 8 DuPont cap

Metal Compatibility:

When dry: Brass, Al, steels, Cd & Ni are unaffected, while Cu, Mg, Al-Mg alloy are slightly affected

When wet: Stainless steels are unaffected; Al sl affected; Cu, brass, Mg, Mg-Al alloy, mild steels are considerably affected

Power by Ballistic Mortar Test – 119% TNT

Power by Trauzl Test – 120% TNT

Rifle Bullet Impact Test – Burned 7%, Un-affected 93%

Shape Charge Effectiveness – ca 120% of TNT

Storage – Dry; Hazard Class 9, Compatibility Group I

Vacuum Stability at 100°C – 1.0cc gas evolved in 48 hrs

Vacuum Stability at 120° – 11+cc

Velocity of Detonation – 7340m/sec for 1 inch diam cast unconfined chrgs. Used in shells, bombs and special ammunition components as an alternate explosive


Ednatol, Aluminized. A mixture of EDNA 40, TNT 20 & Al 20, OB to CO₂ –60.2%. This
Ethylenedichloride. See 1,2-Dichloroethane in Vol 5, p D1209-L and Sax, 3rd edit (1968), p 744

**Ethylendiglycolamide and Derivatives**

**N,N’-Ethylendiglycolamide**, 
HO\(\text{CH}_2\text{CO.NH.CH}_2\text{CH}_2\text{NH.CO.CH}_2\text{OH}\); mw 167.17; crys, mp 141°. It can be prepd by slowly adding 17.5g of 68.8% aq ethylene-diamine to 36g of methyl glycolate. After addn, the soln is partly evaporated by heating under reduced pressure on a water bath and then cooled. The resulting crystalline solids are separated and purified by recrystallization from 95% ethanol (Ref 2).

It gives on nitr ation the following expl compds:

**N,N’-Ethylendiglycolamide Dinitrate**, 
O\(_2\text{N.O.CH}_2\text{CO.NH.CH}_2\text{CH}_2\text{NH.CO.CH}_2\text{ONO}_2\); mw 266.17, N 21.05%; OB –54.1%, wh crys, mp 161–62°. It can be prepd by dissolving 10g of ethylendiglycolamide in 50ml of wh nitric acid, followed by heating the soln for 15 mins at 50–60°. On pouring the soln into large vol of ice-water, a wh solid separates which can be filtered off, washed with w, dried, recrystallized from chlf contg a small amt of alc (Ref 2). No props are given in Ref 2.

**Nitro-N,N’-ethylendiglycolamide Dinitrate**, 
O\(_2\text{N.O.CH}_2\text{CO.N(NO}_2\text{)CH}_2\text{CH}_2\text{NH.CO} \cdot \text{CH}_2\text{ONO}_2\); mw 311.17, N 22.51%, OB to CO\(_2\) –33.4%; crys, mp 100–101°(decomp). It can be prepd by dissolving 2g of ethylendiglycolamide in a cold mixture of 5ml of wh nitric acid and 8ml of acetic anhydride, allowing to stand for 10 mins at RT and then pouring the soln on ice. The resulting wh solid is collected on a filter, washed with w, dried and crystallized from chlf contg some alc (Ref 2). No props are given in Ref 2.

**Dinitro-N,N’-ethylendiglycolamide Dinitrate**, 
O\(_2\text{NO.CH}_2\text{CO.N(NO}_2\text{)CH}_2\text{CH}_2\text{NH.CO} \cdot \text{CH}_2\text{ONO}_2\); mw 356.17, N 23.60%, OB to CO\(_2\) –18.0%; wh crys, mp 135–36°. It can be prepd by dissolving 2g of Nitro-N,N’-ethylendiglycolamide Dinitrate in 8ml wh nitric acid, heating the soln at 60° for 30 mins and pouring on ice. Then wh solid is separated by

**Ethylendibromide, Ethylenebromide or 1,2-Dibromoethane**, Br\(\text{CH}_2\text{CH}_2\text{Br}\); mw 187.88; colorless, nonflamable, poisonous liquid; sp gr 2.180 at 20°/4°, fr p 10°, bp 131.7°, n\(_D\) 1.5357 at 25°; sl sol in w; miscible with most solvents and thinners. It can be prepd by the action of bromine on ethylene gas; used as scavenger for lead in gasoline; as solvent for fats, oils, waxes, gums, etc and in prepn of celluloid. Avoid breathing vapor; absorbs thru skin.

filtration, washed with W, dried and crystallized from a mixture of chl & ethyl acetate (Ref 2). No props are given in Ref 2

Refs: 1) Beil, not found  2) R. Adams & C.S. Marvel, OSRD 86 (1941), pp 12-13, 37-42

**Ethynedinitritotetraacetic Acid.** Same as Ethynediaminotetraacetic Acid

2,2'-Ethynedinitritoino)diethanol Dinitrate.
See 2,2'-Ethynedinitritoino)diethanol Dinitrate under 2,2'-Ethynedinitritoino)diethanol and Derivatives in this Vol.

1,5-Ethylene-3,7-dinitro-1,3,5,7-tetrazao-2,4,6,8-cyclooctane. See 3,7-Dinitro-1,5-endoethylene-1,3,5,7-tetraza-2,4,6,8-cyclooctane under 1,5-Endoethylene-1,3,5,7-tetraza-2,4,6,8-cyclooctane and Derivatives in Vol 5 of Encycl, p E90-L

**Ethynedioxoyamine (called a,a'-Ethynedihydroxyamin in Ger),**
CH₂.O.NH₂

CH₂.O.NH₂; mw 92.10, N 30.42%. sl aromatic liq, bp 203° & 105° at 23mm press, explodes mildly on distillation at normal press; miscible with water, alc & chlf. It was prep'd from the K salt of 1,1'-ethynedioxoyamine-2,2-diisulfonic acid by reaction with perchlormic acid and heating the aq soln with concd alkali added

The following salts were prep'd:

*Hydrochloride Salt, C₆H₄N₂O₂ + 2HCl; shiny plts, mp 233°*

*Nitrate, C₆H₄N₂O₂ + 2HNO₃, mp 124°, detonates on heating above its mp*

*Sulfate, C₆H₄N₂O₂ + H₂SO₄; crystals (from w), mp 260°; v sl sol in alc, acid in aq soln

Refs: 1) Beil 1, 470 & [523]  2) W. Traube et al, Ber 53, 1489 (1920) & CA 15, 84 (1921)

**Ethynedioxoyamine Perchlorate (EDAP)**
H₂NOC₂H₄CH₂ONH₂ + 2HClO₄. Accdg to Rept E1-221, Dept of Defense, Amened Services Explosives Safety Board, Washington, DC 20315 as quoted in Ref: "A low-order ex-

plosion of EDAP is believed to have occurred while it was being purified. A chemist had been working on the synthesis and character-

ization of this sensitive material. Both men present in the room died. Explosion caused fire, a minor secondary explosion, noxious irritating fumes and smoke, damage to contents of the lab and an adjacent lab."

Refl: Expols & Pyrots, The Franklin Inst Newsletter Vol 1, No 6 (June 1968)

**Ethynenedioxoybenzene or Pyrocatechol,**
**Ethylene Esters.** See Benzodioxan in Vol 2, p B66-R

**Ethynediphenyldiamine.** See N,N'-Diphenyl-
ethynediamidine in Vol 5, p D1457-R

**Ethyneditetrazyloazide,**

\[
\begin{array}{c}
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\text{N} \\
\end{array}
\]

N₉C — N.CH₂.CH₂.N — C.N₈

mw 248.18, N 79.04%. It is a highly brisant compd which can be easily initiated by sparks or flame. When absorbed in a porous combustible material like cellulose or paper, it has still an excellent igniting power for expls.

It gelatinizes NC, thus forming an easily ignited gelatin of high brisance.

Friedrich patented the compd for use in primers and detonators and as a core of detonating fuses

Refs: 1) Beil, not found  2) W. Friedrich, USP 2170943 (1939) & CA 34, 265 (1940)

**1,1'-Ethynediurea Dinitrate.** See under 1,1'-
Ethynedibisurea and Derivatives in this Vol

**Ethynediurethane Azide.** See under Ethynedibisurea Azide and Derivatives in this Vol

**ETHYLENEGLYCOL AND DERIVATIVES**

Ethyleneglycol, Ethanol, 1,2, Glycol (Abbr by us Ge); Ger names are Glykol or Äthylenglkoll; HOCH₂.CH₂OH; mw 62.07; colorless,
syrupy, sweet-tasting liquid; sp gr 1.1155 at 20°C; d(tent) 1.1136 at 20°C; fr p -13.5°C, bp 197.2°C, nD 1.4316 at 20°C & 1.430 at 25°C; flash p (Cleveland open cup) 240.8°F, fire p 250°F. Solubilities and other properties of GC are listed after the prep. Preparation of Ethylene glycol

It was first prep'd in 1865 in France by C.A. Wurtz (pronounced Wurz) (1817-1884) by saponification of ethyleneglycolacetate with KOH, and its structure was established in 1859. In 1860 it was prep'd by the hydration of ethylene oxide (Refs 1 & 7a). For about a half century GC remained a laboratory curiosity. Accdg to Naoum (Ref 3, p 211), the first statements for using it in prep'ns of EGDN (Ethylene glycol Dinitrate) proposed as a possible additive to NG (Nitroglycerin) for lowering its fr p - appeared in GerP 179789 of 1904, EnglP 12770 (1912) and in MP 16, 73 (1912) & 17, 175 (1914). However, at that time there appeared to have been no commercial manuf of GC or its dinitrate. The scarcity of glycerin in Germany during WWI turned attention to NGc as a possible substitute for NG, and all methods for prep'g it were studied. The commercial process of manuf GC from ethanol via ethylene, ethylenechlorohydrin and ethylenedichloride was therefore developed, and during WWI many thousands of kilos were manuf'd, mainly by the firm of Th. Goldschmidt in Essen, and furnished the explosives industry. It was nitrated to NGc, partly as such and partly in mixts with NG as a completely equivalent substitute for the latter in mining expls (Ref 3).

Accdg to Cumme & Johnston (Ref 15), manuf in the USA of GC and NGc began in 1925, when the first large scale plant was established by Carbide and Carbon Chemical Corp at South Charleston in West Virginia. In 1927 the USBurMines approved 25 ethylene glycol derived expls as being permissible for use in coal mines and by 1929, practically every manufac'turer of Dynamite in the USA was using EGDN as an antifreeze component (See also under DYNAMITE in Vol 5, pp D1590 to D1593-R, D1594-L, D1599 & D1601). Manufacture of Ethylene glycol. Several methods of manuf, mostly of German origin, are described in Naoum (Ref 3, pp 212-16)

Most US plants used at the time of publication of Cumme & Johnston's book (Ref 15) are of the following three methods:

1) Hydration of ethylene oxide, which can be prep'd from ethylene by direct action of oxygen in presence of a catalyst (such as silver). This process is based on Lefort's discovery of 1931

H₂C=CH₂ + 0.5O₂ $\rightarrow$ H₂C.O.CH₂ + CO₂ + H₂O
H₂C.O.CH₂ + H₂O $\rightarrow$ HOCH₂.CH₂OH (Yield ca 50%) (See also Ref 13)

2) Hypochlorination of ethylene to ethylene-chlorohydridin, followed by hydrolysis with Na bicarbonate:

H₂C=CH₂ + HOCl $\rightarrow$ HO.CH₂.CH₂Cl
NaHCO₃ + H₂O $\rightarrow$ HOCH₂.CH₂OH + CO₂ + H₂O + NaCl

The yield is 65-70%

Note: Ethylene can be prep'd in high yield by passing ethanol vapor over coke w/ phosphoric acid in towers (Ref 3, p 212, footnote 11)

3) Formaldehyde is made to react at high pressure and high temperature with CO and water to produce glycolic acid:

CH₂O + CO + H₂O $\rightarrow$ HOCH₂.COOH

The acid is purified by esterification:

HOCH₂.COOH + ROH $\rightarrow$ HOCH₂.COOH + H₂O

and then reacted with hydrogen at high pressure and high temperature in the presence of chromite catalyst:

HOCH₂.COOH + 2H₂ $\rightarrow$ HOCH₂.CH₂OH + ROH

The yield is about 75%

The duPont & Co in 1940 put in operation a unique plant at Belle, West Virginia, in which glycol was manufd by hydrogenation of methylglycolate, the raw materials for which included its own high pressure synthesis products: formaldehyde and methanol.

One US plant manuf'd, since about 1948, GC starting with petroleum, chlorine and caustic soda. At first a mixt of ethylene- and propylene oxides was obtd and this was treated with Na hypochlorite (obtd from NaOH+Cl₂) and then hydroyized with NaOH (Ref 15)

Properties of Ethylene glycol (Refs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16 & 17)

Acid Dissociation Constant at 19°C $-$

$K_a = 5.7 \times 10^{-11}$

Azeotropes of GC are listed in Ref 15, p 30

Coefficient of Expansion at 20°C - 0.00062/°C (Ref 15, p 28)

Dielectric Constant at 20°C and 150 meters - 38.66esu (Ref 15, p 28)

Electrical Conductivity at 25°C - 1.07 x 10⁻⁶mhos (Ref 15, p 28)
Entropy of Formation at 25° = 39.9 kcal/mol/°C
(Ref 15, p 28)

Flammability Values — See Ref 15, p 39

Germicidal Value — As a preservative against bacterial yeast, or mold growth, it showed a close approach to ethanol and was superior to glycerol (Ref 2)

Heat of Combustion at C_p & 20° = 283.3 kcal/mol
(Ref 15, p 28)

Heat of Combustion at C_v & 20° = 285.0 kcal/mol
(Ref 15, p 42)

Heat of Dilution — on mixing Gc with water some contraction with evolution of heat takes place; for example, on mixing one mol of Gc with 2 mols of water 0.60 cal is evolved with formation of C_2H_4(OH)_2·2H_2O. It was also reported that on mixing 37% of Gc with 63% of water a hexahydrate was formed (Ref 2)

Heat of Formation at 20° — minus 108.1 kcal/mol
(Ref 15, p 28)

Heat of Fusion — 44.76 kcal/g or 2.66 kcal/mol
(Ref 15, p 28)

Heat of Vaporization at 760mm — 191 kcal/g

Hygroscopicity — very high; increase in wt 30% in one week or 60% in 2 weeks with formation of dihydrate (See also Ref 15, p 44)

Infrared Absorption Spectra. See Ref 15, p 27

Molal Entropy at 25° — minus 105.4 kcal/mol/°C
(Ref 15, p 28)

Solubilities of Gc in Various Solvents per 100g. at 25°C: completely miscible with water, lower aliphatic alcs, aldehydes & ketones; AcOH, pyridine, chlorobenzene, phenol, furfuraldehyde, and glycerol; slightly dissolves in CS_2, chlfl, xylene; solubilities in other solvents: DBuPh 0.5, toluene 3.1, o-DCP Bz 4.7, CCl_4 6.6 and eth 8.9%. Insol in Gc are NC, cellulose acetate, paraffin oil & other oils, rubber, and sac; sol in animal glue and dextrin contains 10% water. Solubilities in 100g Gc at 25° of some inorganics: K_{2}SO_4-in sol, KClO_3 1.21, KClO_4 1.03, KCl 5.18, NaCl 7.1, NaClO_3 16.0 and NaClO_4 75.5. (See also Ref 15, p 47)

Specific Heat at 20° — 0.561 kcal/g/°C (Ref 15, pp 29 & 49)

Specific Ignition Temperature — 775°F (413°C) (Ref 15, p 39)

Surface Tension at 20° — 48.4 dynes/cm
(Ref 15, p 29)

Thermal Conductivity at 20° — 0.000690 cal/cm/sec/cm²/°C

Thermal Stability. See Initial Decomposition Temperature

Toxicity. Hunt (Ref 6) claimed that toxicity of Gc is high and might be fatal. This is due to oxidation of Gc to very poisonous oxalic acid which takes place in the body, not immediately, but after a while. It is recommended by Hunt to forbid using Gc in foods. Lethal dose is considered to be 100ml. Hunslock (Ref 5) considers that lethal doses are higher than 100ml. More detailed discussion on toxicity is given in Ref 15, pp 300—302 and in Ref 15a

Uses of Gc. Besides use as a source of manuf. of the expl Ethylene glycol Dinitrate and of some other derivatives, it has been used on a large scale as an antifreeze liquid for automobile cooling systems. One of such materials is known as "Prestone". Gc has also been used in automobile brake fluids and in solvent mixtures for various products

Vapor Pressure at 20° — 0.06mm Hg (Ref 15, p 29) at 60° 1.6, and 100° 25mm (Ref 15a)

Viscosity (absol) at 20° — 20.93cp (Ref 15, p 29)

Viscosity in centipoises. See Ref 15, p 57

Under the name of Ethylenglycol Condensation Polymers, Cume & Johnston (Ref 15) placed glycols with several ethylene groups such as diethylene glycol (described in Vol 5, p D1231-R), triethylene glycol, HOCH_2·CH_2·OCH_2·CH_2·OCH_2·CH_2·OH, and numerous group of compounds known as Polyethylene glycols, which are described below

Only lower members of polyethylene glycols are of interest from the point of view of prep of expls

Cume & Johnston (Ref 15) describe these compounds on pp 153—202 and give their toxicities on pp 302—317

Under the name of Ethylene glycol Derivatives, A.B. Boese et al discussed in the book of Cume & Johnston (Ref 15, pp 114—52 with 415 refs) esters, ethers, ether-esters, alkyds, acetals, ketals, etc of Gc. Their toxicities are given by H.F. Smyth Jr in the same book on pp 305—17

E. Vernazza discussed in Industria Chimica, Vol 4, pp 990—999 (1929) some expl esters of ethylene glycol

Nitration of ethylene glycol, which can be carried out in equipment used for the nitration of glycine, was discussed by B.P.
Enoksson in Swed P 154069 (1956) & CA 50, 14230 (1956) and its kinetics was discussed by J. Roth, F.S. Stow, Jr & D.L. Koubi in IEC 50, Sept 1958, p 1283 & CA 53, 5125 (1959)

Refs for Glycol: 1) Beil 1, 465, (242), [514] 

Ethyleneglycol: Analysis and Test Methods.

Hillenbrand describes in Ref 1, pp 328-51 the following subjects: 1) Qualitative Identification, 2) Quantitative Determination, and 3) Specifications and Methods of Testing Commercial Glycols

1. Qualitative Identification includes A. Colorimetric Tests: a) Oxidation with bromine or permanganate (p328); b) Oxidation with nitric acid (p329); c) Oxidation with periodic acid (p329); d) Reaction with certain phenols (p330)

B. Preparation of Solid Derivatives, such as: a) Esters of benzoic acid and nitrobenzoic acids (p331); b) Alkyl N-Acylcarbamates (Phenyl- and α-Naphthylurethanes) (p331); and c) Bis (triphenylmethyl) Esters (p332)

2. Quantitative Determinations include: A. Acetylation methods by: a) Acetic anhydride-pyridine reagent (p333) b) Acetyl chloride (p335) and c) Phthalic anhydride (p336)

B. Oxidation methods by: a) Periodic acid (p337); b) Lead tetraacetate (p339); c) Potassium dichromate (p340); and d) Potassium permanganate (p342)

C. Miscellaneous methods: a) Reaction with hydriodic acid (p342); b) Reaction with ammonium hexanitrocate reagent (p343); c) Precipitation with silico-tungstic or phosphomolybdc acid (p344); and d) Determination as the diethyl ether (p345)

3. Specifications and Methods of Testing Commercial Glycols include (pp345-50): a) Specific gravity 1.1151 - 1.1156; b) Distillation at 760 mm: initial pp min 193°, dry point max 210°; c) Acidity % by wt as AcOH, max 0.01%; d) Moisture, % by wt, max 0.30%; e) Water solubility at 25° - complete; f) Ash, g/100ml, max 0.005%; g) Color, Pt-Co(APHA) units, max 15; h) Odor - mild; I) Suspended matter - substantially free
In Ref 2 is given the following general equation of oxidation of glycols (compounds with adjacent hydroxyl groups) by periodic acid:

$$R-CH-\text{OH} + HIO_4 \rightarrow R-CH + \text{H}_2\text{O} + \text{HNO}_3$$

In Ref 3, under "Ethanol Determination by Estimation of Its Hydroxyl Groups Using Various Esterification Procedures" are described methods which are applicable to analysis of glycols.

(See also this Vol of Encycl under "Ethanol Determination by Estimation of Its Hydroxyl Groups Using Various Esterification Procedures")


Ethylene glycol (Technical) for use as a heat-transfer fluid and laboratory testing reagent, is covered by US Military Specification MIL-E-9500A, 21 June 1968 and Amendment 1, 24 June 1969

Chemical Requirements:

1) Chlorides — No ppt present when examined as in Test 4.3.1
2) Total glycol, minimum 99.5% when examined as in Test 4.3.2
3) Acidity (calced as AcOH), maximum when examined as in Test 4.3.3
4) Ash residue: max. 0.005 g in 100 ml when examined as in Test 4.3.4
5) Distillation: when examined as in Test 4.3.5

- Initial bp 192°C, min 95% distilled, 200°C, max

Physical requirements:

- Dry point, 208°C, max
- Water solubility at 25°C (77°F) when examined as in Test 4.3.6 — miscible with water in all proportions

Tests:

- Water, in accordance with ASTM D1193-66, and reagent grade chemicals shall be used for testing. Blanks shall be run and corrections applied when significant.

Tests shall be conducted as follows:

4.3.1 Chlorides. Place 10 ml of the material in a 30 ml test tube. Add 10 ml of water and mix. Add 10 drops of concd nitric acid, agitate the mixture, and filter. Add 10 drops of 3 percent aqueous soln of silver nitrate to the filtrate. No precipitate shall settle out within 30 minutes after the addition of silver nitrate soln. A slight turbidity will not be cause for rejection.

4.3.2 Water content. Water content shall be determined in accordance with Federal Test Method Standard No 791 Test Method No 3253 (ASTM D1744-64) except 10 to 40 grams (9 to 35 ml) of sample, depending on the anticipated moisture content, shall be used.

4.3.3 Acidity. Acidity shall be determined by measuring 108 ml (120 g) of sample in a graduate and transferring it to a 250 ml Erlenmeyer flask. A few drops of 1.0% alcoholic solution of phenolphthalein indicator shall be added and the sample titrated with standard 0.1 N alc KOH to the first pink end point permanent for 15 seconds. The calculation is as follows:

- \( \text{ml KOH} \times 0.005 = \text{Acidity, percent by weight as acetic acid} \)

4.3.4 Ash. Ash residue shall be determined by measuring 50 ml of the sample in a graduate and transferring to a 125 ml platinum dish which has been ignited to constant weight, cooled in a desiccator, and cared to the nearest 0.1 mg. The dish shall be heated until the vapors continue to
burn after the flame is withdrawn. The combustion shall be protected from drafts and the vapors allowed to bum spontaneously until the liquid is consumed. The dish shall then be ignited to a dull red heat, allowed to cool in a desiccator, and weighed to the nearest 0.1 mg. The ash residue per 100 ml shall be calculated as follows:

\[ g \text{ ash per } 100 \text{ ml} = g \text{ residue } \times 2 \]

4.3.5 Distillation. Distillation shall be conducted according to Federal Test Method Standard No 141 Test Method No 4301.1, except that distillation shall be conducted at a pressure of 760 mm of mercury or corrected thereto by adding 0.043°C for each mm under 760 mm or subtracting for every mm over 760 mm.

4.3.6 Miscibility with water (Water Solubility). Miscibility with water shall be determined by transferring 25 ml of the sample at 25°C (77°F) to a 100 ml glass stoppered graduated and adding 25 ml of water at 25°C in 5 ml portions, shaking the graduate well after each addition. Twenty-five ml of the sample shall be added to 25 ml of water in the same manner. If there is no cloudiness, stratification, or turbidity at any time, the sample shall be considered completely miscible.

4.3.7 Color. Color shall be determined in accordance with ASTM D2108-64.

4.3.8 Flash point. The flash point of the material shall be determined according to Federal Test Method Standard No 791 Test Method No 1103.6 (ASTM D92-66), except that the fire point need not be determined.

4.3.9 Odor. Odor shall be determined by pouring 5 ml of the sample on clean filter paper and observing the odor at once.

4.3.10 Specific gravity. Specific gravity of the material shall be determined at 20/20°C according to Federal Test Method Standard No 791 Test Method No 402.2 (ASTM D941-55).

4.3.11 Suspended matter. Place 500 ml of the sample in a 1000-ml stoppered bottle, and let set for 2 hours. Invert the container, hold up to a well-lighted background, and observe for any suspended matter. There shall be no suspended matter visible in the sample.

**Ethylene glycol Polymers; Polyethylene glycols or Polyglycols.**

Curme and Johnston (Ref 13, pp 176-202) assign this name to any ethylene glycol condensation polymer higher than triethylene glycol. This includes several liquid polymers, such as tetraethylene glycol and polyethylene glycols 200, 300, 400 and 600, which are manufactured in this country. (The numbers 200 etc signify the average molecular weights of these compounds). The solid polymers are known as "Carbowax" 1000, 1500, 1540, 4000, 6000, if manufactured by the Carbide and Carbon Co, and as "Polyglycol" E1200, E4000, if produced by the Dow Chemical Co.

In Germany, polyethylene glycols are known as Polyglykol P-*, with a numerical suffix that refers to the units of ethylene oxide involved in its manuf. For instance, Polyglykol P-6, P-8, P-9 and P-12 are yellow, viscous liquids; P-18 a semi-solid brown wax and P-60 & P-80 yellow waxes. The so-called "Oxydwichs" has an approximate molecular wt of 4000 and is offered commercially.

The first known polyethylene glycol was prepared by Lourenco (Ref 2a) by heating a mixture of ethylene glycol and ethylene dibromide in a sealed tube at 115° to 120°. This glycol corresponded approx to hexa-ethylene glycol. In the same year, Wurtz pronounced Wurtz (Ref 26) obtd some polyethylene glycols by heating ethylene glycol, ethylene oxide and water for several weeks. More work on polyethylene was done later by Wurtz (Refs 3 & 4). Many methods of prep of polyglycols are given in Curme and Johnston's book (Ref 13), among which are the method of Staudinger & Schweitzer (Ref 5) involving the polymerization of ethylene oxide under the influence of catalysts, such as stannic chloride. Staudinger & Lohmann (Ref 6) detd rates of polymerization with various catalysts (See Table 7.9 in Ref 13, p 178).

Matignon et al (Ref 6a) prepared polyethylene glycols by hydration of ethylene oxide in presence of 0.5% sulfuric acid as catalyst. Perry & Hibbert (Ref 8) described the first direct method for synthesizing a single polyethylene glycol. The method involved the reaction between the dichloride of a pure low-molecular-weight polyglycol and two mols of the monosodium alcoholate of another pure polyglycol. Using this procedure, polyglycols with as high as 186 ethylene groups were obtained (See also Refs 9 & 10).
Commercial methods of prep of polyglycols are described by Ellis (Ref 7) and by Cume and Johnston (Ref 13). One of the American methods consisted of adding to water and ethyleneglycol (or to diethyleneglycol containing a catalytic proportion of NaOH), ethylene oxide at such a rate as to maintain the temperature of the liquid between 120° and 135°. The system was then maintained at the above temperature for 2 to 5 hours at a pressure of 60 psi; the reactor was cooled with water at some heat was liberated during the reaction. The mixture was then neutralized and filtered.

Note: The reaction was considered completed when the pressure in the system at constant temperature remained unchanged for at least one hour.

The German method of prep was described by Brandner and Goepp (Ref 11).

The physical properties of polyethylene glycols vary with molecular weight, either increasing or decreasing. Such properties as freezing point, flash point, density and viscosity increase with an increase in molecular weight, while the vapor pressure, hygroscopigity and solubility in organic compounds decrease.

All the polyglycols are soluble in water and are miscible with many waxes, gums, oils, starches and organic solvents. Properties of various polyglycols are given on pp 181 to 185 of Ref 13.

Uses: Polyglycols are widely used in cosmetics, resins, plasticizers, textiles, agriculture, coatings, in electronics and as lubricants for rubber molds, textile fibers, etc.

Toxicity

Liquid polyethylene glycols 200, 300 and 400 are about as toxic as triethylene glycol, but those with higher molecular weights are less toxic.

Solid polyethylene glycols are less toxic than liquid ones and their toxicity decreases with increase in molecular weight.

Analysis and Tests

Cume and Johnston's book, pp 328-350 gives specifications and methods of analysis of polyethylene glycols as high as triethylene glycol but not for higher ones.


Ethylene glycol-Sugar Mixture, Nitrotated. In order to prepare a cheaper expl, the Germans used to add about 25% sugar to ethylene glycol and then nitrate the mixture in the same manner as straight glycol or straight glycerin. The resulting product was a mixture of EGDN and Heptanitrosaccharide. It was a powerful expl with N content 17.8 to 17.9%.

Ref: Naoim, NG (1928), 255

Ethylene glycol acetate or Glycol Monoacetate, HO-CH₂-CH₂-OOC.CH₃, mw 104.10; colorless, nearly odorless liq, sp gr 1.08, bp 181-82°, partially sol in w, sol in alc & eth. It can be prep from ethylene glycol and AcOH or by passing ethylene oxide into hot AcOH contg AcONa or sulfuic acid. Its toxicity is discussed in Ref 2, pp 311-12 and in Ref 4. It is used as a solvent for NC, cellulose acetate or camphor (See also Ethylene glycol Diacetate).


Ethylene glycol Acetate Nitrate or Glycol Monoacetate Mononitrate, O₃N.O.CH₂-CH₂-OOC.CH₃, mw 149.10, sp gr 1.29 at 18°, oil, insol in w, sol in dil mineral acids. It was prep by dissolving glycol monoacetate in nitrosulfic acid. (See also Ethylene glycol Diacetate).

Refs: 1) Beil 2, 142 2) L. Henry, Ann (4) 27, 259 (1872) 3) Cume & Johnston (1952) - not found
Ethylene glycol-bis(trinitrobutyrate). See Ethylene glycol-di(trinitrobutyrate)

Ethylene glycol Butylether, Glycol monobutyl Ether or 2-Butoxyethanol,
HO.CH₃.CH₂.OC₄H₉, mw 118.18, colorless liq with mild odor, sp gr 0.9019 at 20/20⁰, nD₁.4190 at 25⁰, bp 171.2⁰, fl p 165⁰F, sol in w & in mineral oils. It can be prepd by many methods described in Ref 3, pp 114–15; industrially it can be prepd by reacting ethylene oxide with butanol, in presence of a catalyst as described in Ref 2. It is used as solvent for NC. resins, spray & brushing lacquers, varnishes etc. Its toxicity is discussed in Ref 3, pp 306 & 309 and in Ref 5

Ethylene glycol Butylether Acetate or Glycol Monobutylether Acetate,
CH₃COO.CH₃.CH₂.OC₄H₉, mw 160.21; colorless liq with fruity odor, sp gr 0.9424 at 20/20⁰, nD₁.420 at 20⁰, fr p −63.5⁰, bp 192.2⁰, fl p (open cup) 190⁰F; very sl sol in w; sol in hydrocarbons and in org solvents. Prepn not found in CA. Used as a high-boiling solvent for NC, lacquers, epoxy resins, etc

Ethylene glycol Condensation Products, Nitrated.
Acldg to Foulon (Ref 2), the Westfälisch-Anhal-tische Sprengstoff AG (Ref 1) proposed using the nitrated glycol (such as ethylene- or diethylene-glycol) condensation products as explosive gelatinizers for NC intended for use in propmts. It was claimed that these nitrated condensation products can gelatinize any kind of NC cold, and for this reason it is not necessary to conduct the extrusion, or rolling operations hot. The resulting NC propmts are uniform in structure, stable and burn uniformly. No additional solvents are required for gelatinization
Refs: 1) Westfälisch-Anhaltische Sprengstoff AG, Ger P 548427 (1931) & CA 26, 3670 (1932)

Ethylene glycol Diacetate or Glycol Diacetate,
CH₃.COOC₂H₅.CH₂.OOC.C₂H₅, mw 146.14; colorless liq with faint odor, sp gr 1.063 at 20/20⁰, fr p −41.5⁰, bp 190.5⁰, vapor pressure 0.3mm Hg at 20⁰, fl p 220⁰F, nD₁.415 at 20⁰; soly in w 14.3% at 22⁰; miscible with alc, ether & benz. It was first prepd in 1859 by Wurtz (pronounced Wurz) from ethylenedibromide (or diiodide) and Ag acetate; Demole prepd it in 1875 from ethylenedibromide and anhydrous K acetate and Seelig patented, in 1887 in Germany, its prepn by boiling for 35 hours a mixture of 74g of ethylenedibromide, 80g of Na acetate and 200g of AOH. Its industrial prepn on a large scale from derivatives of the chlorination of natural gas was patented in Germany in 1921 by Meyer and in the USA in 1922 by Rodebush (Refs 1 & 2)

In CondChemDict (Ref 4) it is stated that it can be prepd from ethylene glycol and acetic acid and ethylenedichloride and Na acetate

Method of purification of commercial diacetate, such as supplied by the Carbide and Carbon Corp is described by Taylor & Rinkenbach (Ref 2, p 1305). From the product boiling at 188⁰ to 189.6⁰ at 739.2mm Hg, the water that may have been present was removed by treatment with Ca chloride. The clear filtrate was kept from contact with moist air and fractionally distilled at 125⁰ and 85mm Hg. The middle and largest of 3 fractions, representing ca 70% of the volume treated, was retained for examination of properties of diacetate. It was found that it is neutral, stable, has a high bp, very low volatility at RT, and a very high solvent power for organic expl compds. For these reasons it is suitable for purification of expls (such as TNT) by crystallization. It also can be used for control of their crystal size. It is less toxic than DEGDN (Ref 3, p 311). See also Ref 5. See also Ethylene glycol Mono-acetate
Ethylene glycol Diacylate, (CH₂=CHCO₂CH₂)₂; mw 170.17; bp 53–7° (0.6mm) and 70° (1mm), sp gr 1.0935 at 26/20°, nD 1.4529 (1.4546) at 20°. It is prepd by refluxing ethylene glycol, acrylic acid, p-toluenesulfonic acid, pyrogallol, and cuprous chloride in benz in the dark; obt 40% yield. It is used to prepare Ethylene glycol di-trinitrobutyrate (qv) Refs: 1) Beil, not found 2) J.G. Burt et al, JOC 17, 1302–4 (1952) & CA 47, 9913 (1953) 3) Kirk & Othmer, Vol 1, (1963), p 289

Ethylene glycol Diethylether, Glycol Diethyl ether (GDEE), 1,2-Diethoxyethane (called in Lange Diethyl Collosolve), C₂H₅O.CH₂.CH₂.OC₂H₅; mw 118.17, colorless liq with sl ethereal odor, sp gr 0.8417 at 20/20°, fr p ~74°, bp 121.4°, fl p 95°F, vapor pressure ~9.4mm at 20°; partially miscible with w. It can be prepd by reacting the Na alcoholate of an ethylene glycol ether with ethyl halide or by reacting diethyl sulfate with the ethylene glycol monoethylether (Refs 2 & 3)

It is used in org synthesis and as a solvent; when added to colloidal systems such as detergents and wetting agents of limited water soly, permits w dilution while reducing, without gelling or clouding. Its toxicity is discussed in Ref 3, p 306 Refs: 1) Beil 1, 467, [518] & [2078] 2) A. Wurtz, AnnChimPhys (3) 55, 431 (1859) 3) Curme & Johnston (1952), 119 & 306 4) CondChemDict (1961), 467–L (Ethylene glycol Diethylether) 5) Sax, 3rd ed (1968), not found

Ethylene glycol Dilactate or Glycol Dilactate, CH₂.O.CO.CH(OH).CH₃
CH₂.O.CO.CH(OH).CH₃; mw 216.19. It may be considered as the parent compd of its dinitrato deriv, although not used for its prep

Ethylene glycol Dilactate Dinitrate, CH₂.O.CO.CH(ONO₂)CH₃
CH₂.O.CO.CH(ONO₂)CH₃; mw 296.19, N 9.46%, Ob to CO₂ ~64.9%. This compd was prepd during WWII by the duPont Co and found to be an expi stable to heat and extremely insensitive to impact. No description of its prep was found

In the International Test at 75°, this compd showed no decom in 48 hrs. Its impact test with 20kg wt was negative at 44.5 inches (Ref 2) Refs: 1) Beil, not found 2) Blatt, OSLDR 2014 (1944) (No prep given) 3) CA, not found thru 1966

Ethylene glycol Dimethylether (EGDME) or Glycol Dimethylether (GDME), also known as 1,2-Dimethoxyethane or Dimethyldisolve, CH₂.O.CH₂.CH₂.OCH₂; mw 90.12; colorless, flammable liq with a mild ether odor; sp gr 0.8683 at 20°, nD 1.3792 at 20° fr p ~69°, bp 85.2°, fl p (open cup) 34°F; pH 8.2; sol in w and hydrocarbons; vapor pressure 61.2mm at 20°. It can be prepd by reacting Na alcoholate of an ethylene glycol methylether with methyl halide. Used as a solvent. Its toxicity is discussed in Ref 3, p 306


Ethylene glycol Dinitrate. See under ETHYLENEGLYCOL NITRITES AND NITRATES

Ethylene glycol Dinitrite. See under ETHYLENEGLYCOL NITRITES AND NITRATES

Ethylene glycol Diphenylether or Di(phenolxy)-ethylen. See Bis(phenyl)ethylene glycol Ether in Vol 2 of Encycl, p B153-R. Its Bis(dinitrophenyl)-ethylene glycol ether, also known as [ethylene glycol-2,4,2'4'-tetranitrophenyl]-ether is on p B153-R and its Bis(trinitrophenyl)-ethylene glycol ether, also known as [ethylene glycol-2,6,2',6'-hexanitrophenyl]-ether is on p B154-L

Addn refs for these compds are listed under Di(phenolxy)-ethylen in Vol 5, p D1470-R

Ethylene glycol-di-trinitrobutyrate (EGTNB) or Glycol-di-trinitrobutyrate (GTNB), CH₂.COO.CH₂.CH₂.C(NO₂)₃
CH₂.COO.CH₂.CH₂.C(NO₂)₃; mw 472.24,
Ethyleneglycol Ethylether, Glycol Monoethyl-ether, Cellosolve or 2-Ethoxy-ethanol-1,
HO.CH₂-CH₂-OC₂H₅; mw 90.12; colorless, nearly odorless liquid, sp gr 0.9311 at 20/20⁰, nD 1.4060 at 25⁰, fr p -70⁰, bp 135.1⁰F, fl p 130⁰F; miscible with w and hydrocarbons. It can be prepd by reacting ethylene oxide with ethanol in presence of a catalyst or by other methods. Its toxicity is discussed in Ref 4, pp 306 & 308 and in Ref 6. It is used as solvent for NC, resins, oils, etc (See Ref 5). It was proposed (Ref 3) in mixture with perchloric acid, as a liquid serving for destruction of land-mines

Ethylene glycol Ethylether Acetate, Glycol Monoacetyl Acetate or "Cellosolve" Acetate, CH₃COO.CH₂-CH₂-OC₂H₅; mw 132.16; colorless liq with mild ether-like odor; sp gr 0.9748 at 20/20⁰, nD 1.4030 at 25⁰, fr p -61.9⁰, bp 156.3⁰F; fl p 135⁰F; sol in w (20%) and miscible with alc, eth, ace and aromatic hydrocarbons; can be prepd by treating ethylene glycol monoethyl ether with acetyl chloride. Its toxicity is discussed in Ref 3, p 313. It is used as solvent for NC, oils & resins; removes varnish and retards "blushing" in lacquers

Ethylene glycolformal or Ethylene glycol Methyline Ether. See 1,3-Dioxane in Vol 5, pp D1405-R to D1406-L

Ethylene glycolglycolate Dinitrate, (O₂NO)CH₂-CH₂-OC(O)CH₂(ONO₂); mw 210.10, N 13.33%, OB to CO₂ -22.8%. It is a liquid expd prepd and examined during WWII by the duPont & Co and found to be less sensitive to impact than NG and of good stability (23 minutes in 65.5⁰C KI Test)
Refs: 1) Beil, not found 2) Blatt, OSRD 1944(1944) (No prepn given) 3) Curme & Johnston (1952), not found

Ethylene glycolglucoside and Derivatives Ethylene glycol-mono-glucoside (EGG), HO.CH₂-CH₂OCHO(CH₂-OH)CHOH.CH(OH)CHOH; mw 224.21, α-form (ndls from alc-EtAc), sol in w & alc, hygroscopic. It is prepd from d-glucose, glycol, water and α-glucosidase from bottom-fermented, air-dried yeast (Ref 3), β-form (cryst from alc-EtAc), mp 137-8⁰, sol in w & alc; prepd from d-glucose, glycol, water and emulsin (Ref 2)

Ethylene glycol-di-glucoside, 2-CH₂-CH₂OCHO(CH₂-OH)CHOH.CH(OH)CHOH; mw 386.36, β-form, cryst, mp 131.8⁰C. It was prepd from glycol, glucose, and water and emulsin (Ref 4)

Ethylene glycolglucoside Nitrate (EGCN). It is prepd as a mixture with NG & EGN by standard nitration procedure of a mixture of glycol glycol & ethylene glycol glucoside (commercial, cong polyethylene glycols, mono- or diglucoside unspecified). The oily product is useful for dynamite formulation
Refs: 1) Beil, not found 2) A.A. Young, USP 2602733(1952) & CA 46, 9312(1952)
Ethylene glycol Lactate or Glycol Monolactate, CH₂O.C₂H₄.OCH(OH).CH₂:\nCH₃OH
mw 134.13, bp 285-70°, 124° (4.2mm), 100° (0.4mm), sp gr 1.1996 at 20°, nD 1.4495 at 20°. It was first prepd by heating the glycol with lactic acid in the presence of a phosphoric catalyst; later prepd using the aluminum isopropoxide exchange with methyl lactate; most recently using the glycol, the acid and a cation exchange resin in the acid form.
Refs: 1) Beil, not found 2) A.G. Evdokimov, Prioda 1940, No 11, 68-70 & CA 38, 718 (1944)

Ethylene glycol Lactate Dinitrate or Glycol Monolactate Dinitrate
CH₂O.C₂H₄.OCH(ONO₂).CH₂:\nCH₃ONO₂ 12.50%, OB to CO₂ -42.8%. It was prepd by du Pont & Co by, presumably, standard nitration of the lactate ester and found, on examination, to be an explosive stable at 75° but decomposing at 105° with evolin, after 17 hours, of 30cc of gas, as 120cc for NG. Its impact sensitivity with 20kg wt was 40 inches for 1/10 shots and 37 inches for 0/10 shots.
Refs: 1) Beil, not found 2) CA, not found 3) Blatt, OSRD 2014 (1944) (Prepn not given)

Ethylene glycol Methylether, Glycol Mono-methyl Ether, 2-Methoxyethanol or Methyl Cellosolve, HO.C₂H₄.OCH₃; mw 76.09; colorless liq with mild agreeable odor; stable; sp gr 0.9663 at 20/20°, nD 1.4021 at 20°, fr p -85.1°, bp 124.6°, fl p 115°F; miscible with w, alc, ketones, glycols & hydrocarbons. It can be prepd by heating sodium glycolate with methyl iodide. Its toxicity is discussed in Ref 5. It is used as solvent for NC, cellulose acetate, resins, etc.
Refs: 1) Beil 1, 467, (244) & [518] 2) M.H. Palomaa, Ber 35, 3300 (1902) 3) Curme & Johnston (1952), 116-17, 141 & 306-08

Ethylene glycol Methyl ether. Same as Ethylene glycol formal

Ethylene glycol Methylether Acetate or Glycol Monomethylether Acetate, CH₃COO.C₂H₄.OCH₃; mw 118.13; colorless liq with pleasant ester odor; stable; sp gr 1.0067 at 20/20°, fr p -65.1°, bp 145.1°, fl p 140°F; sol in w, miscible with the common org solvents. It can be prepd by treating ethylene glycol methyl ether with AcCl and pyridine. Its toxicity is discussed in Ref 3, p 313 and in Ref 5. It is used as solvent for NC, cellulose acetate, gums, resins, waxes and oils.

Ethylene glycol Monacetate. See Ethylene glycol Acetate in this Vol

Ethylene glycol Monacetate Nitrate. See Ethylene glycol Acetate Nitrate in this Vol

Ethylene glycol Monoalkyl Ethers are compds of general formula RO.C₂H₂.OH, where R stands for methyl, ethyl, propyl, butyl, etc radicals. They are described here as Ethylene glycol Butylether, Ethylene glycol Ethylether and Ethylene glycol Methylether. Their toxicities are described in the following refs:
2) H.W. Werner et al, "Effects of Repeated Exposures of Rats to Vapors of Monoalkyl Ethylene Glycol Ethers", JIndHygToxicol 25(8), Oct 1943, pp 374-79 (8 refs)
4) Curme & Johnston (1952), 305-09 (Toxicity
of alkyl ethers of Ethyleneglycol
5) Sax, 3rd edit (1968) (Under compd name)

**Ethyleneglycol Monobutylether.** See Ethyleneglycol Butylether

**Ethyleneglycol Monobutylether Acetate.** See Ethyleneglycol Butylether Acetate

**Ethyleneglycol Monoethylether.** See Ethyleneglycol Ethylether

**Ethyleneglycol Monoethylether Acetate.** See Ethyleneglycol Ethylether Acetate

**Ethyleneglycol Monolactate.** See Ethyleneglycol Lactate

**Ethyleneglycol Monolactate Dinitrate.** See Ethyleneglycol Lactate Dinitrate

**Ethyleneglycol Monomethylether.** See Ethyleneglycol Methylether

**Ethyleneglycol Monomethylether Acetate.** See Ethyleneglycol Methylether Acetate

**Ethyleneglycol Mononitrate.** See under ETHYLENEGLYCOL NITRITES AND NITRATES

**Ethyleneglycol Mononitrite.** See under ETHYLENEGLYCOL NITRITES AND NITRATES

**Ethyleneglycol-Mononitrite-Mononitrate.** See under ETHYLENEGLYCOL NITRITES AND NITRATES

**Ethyleneglycol Monophenylether.** See Ethyleneglycol Phenylether

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**ETHYLENEGLYCOL NITRITES AND NITRATES**

*Ethyleneglycol Nitrite or Glycol Mononitrite,*

\[ \text{CH}_2\text{OH} \]

\[ \text{CH}_2\text{ONO}^- \text{N} 91.07, \text{N} 15.38\%, \text{OB to CO}_2 \]

\[ -61.5\%. \text{ Prepn of this compd is not given in the open literature} \]

*Refs: 1) Beil, not found 2) CA, not found*

**Ethyleneglycol Nitrite-Nitrate or Glycol Mononitrite-Mononitrate,** \[ \text{CH}_2\text{ONONO}^- \text{N} 136.06, \]

N 20.59\%, OB to CO\textsubscript{2} \[ -11.8\%, \text{bp} 53-66\textdegree(20\text{mm}) \] (Ref 5)

A. Kekulé prep'd in 1869 an unstable liquid (known now as Kekulé Oil) when he passed ethylene thru a cooled nitric-sulfuric acid mixture, which he designated as ethyleneglycol nitrate-nitrite. Later, Wieland & Sakellarios (Ref 2) showed that this product was a mixt of ethyleneglycol dinitrate and the nitric acid ester of 2-Nitroethyl Alcohol (See also Ref 4)

Naomí (Ref 3) gives the following equation in prepn of nitrite-nitrate from ethylene:

\[ \text{CH}_2 \quad + 2\text{HONO}^- \quad \text{CH}_2\text{ONO}^- + \text{H}_2\text{O} \]

\[ \text{CH}_2\text{ONO}^- \]

and then the nitrataion continues with formation of Glycol Dinitrate and nitrous acid:

\[ \text{CH}_2\text{ONO}^- \quad \text{CH}_2\text{ONO}^- \quad + \text{HONO}^- \quad \text{CH}_2\text{ONO}_2^- \quad \text{CH}_2\text{ONO}_2^- \]


**Ethyleneglycol Nitrate, Glycol Mononitrate, Nitro-1,2-ethanediol or Mononitroglycol,**

\[ \text{H}_2\text{O}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{ONO}^- \text{N} 107.07, \text{N} 13.08\%, \text{OB to CO}_2 \]

\[ -37.4\%; \text{colorless, somewhat volatile liquid, with faint aromatic odor; sp gr} \]

\[ 1.348 \text{ at 20/4\degree} \text{ fr p below} -20\degree \text{ bp 91-2\degree} \text{ in a vacuum of a water jet pump and decomp at atm pressure; miscible with w and sol in alc, eth & chlf; dissolves in concd sulfuric acid with considerable evolution of heat, so that in the dem of the nitrogen content by Nitrometer Method (See Vol 1 of Encycl, pp A373-A376)*} \]
It should be first dissolved in moderately strong sulfuric acid and then coned sulfuric acid added gradually.

It was first prep'd in 1872 by Henry (Ref 1 & 2) by the action of Ag nitrate on bromo-hydron. It can also be prep'd by nitration of glycol with concentrated nitric acid (free of N oxides) as described by Naoum (Ref 3, p 227). In industry it is formed as a by-product into the manuf of Dinitroglycol. It is slightly more viscous than DNGc and is a good gelatinizer for NC. It is a rather powerful explosive, but has not been considered for commercial expl compos because it has no advantage over the dinitrate and, moreover, its manuf is more difficult and its high sol in water is a serious disadvantage. Its heat of expln is 943.7 cal/g at CV with water liq or 855.6 with water gas; molecular heat of formation 90.0 kcal and Trautz Test value 375cc (in glass tube with sand tampering) against 650cc for Dinitroglycol. Its toxicity is discussed in Ref 4, p 312.


Addl Refs for EGMN: A) V. Öhman, Ing VetenskapsAkadHandl No 139, 48pp (1936) & CA 30, 5559 (1936) B) W.F. Von Oettingen, NatlnlnstHealthBull No 186, 76pp (1946) & CA 41, 809 (1947) (Toxicology)

Ethylene glycol Dinitrate, (ONO)CH₂CH₂ ONO; mw 120.07, N 23.32%, OB to CO₂ = 26.7%; colorless liq, sp gr 1.2156 at 0º, fr p -15º, bp 96-98º, nD 1.3884 at 18.5º, toxic; insol in w; sol in edh, benz & acer; reacts with ethanol to form ethyl nitrite. On standing it decomposes to oxalic acid and decomposes by alkalis. It can be obtd by distilling Glycerol Nitrate with somewhat more than the theoretical quantity of ethylene glycol (Ref 3) or by treating the glycol with HNO₃ (Ref 4). Its expl properties were not reported.


Ethylene glycol Dinitrate (EGDN or EGdN), Nitroglycol (NGc), Dinitroglycol, Dinitrodimehylene or Ethylene Dinitrate, CH₂.O.NO₂

EG₂O₃NO₂; mw 152.07, N 18.42%, OB to CO₂ ±0%, OB to CO +21%; colorless volatile liquid when in pure state; yellowish liquid in crude state; sp gr 1.488 at 20/4º or 1.480 at 25º; bp 1.4452 at 25º or 1.4472 at 20º, fr p -22.75º (vs +13.1º for NG); fr p given in Ref 19, p 132 is -22.3º; bp 199º at 760mm Hg (with decom). Wieland & Sakellarios (Ref 3a as quoted in Ref 5, p 1499) found EGDN to boil at 105.5º under a pressure of 19mm Hg, but when quickly heated under atm pressure it exploded at 215º. This was preceded by partial decom and analogous to that found in case of NG.

Its solubility and other props are given after description of its methods of prep.

L. Henry was the first to prep EGDN in a pure state (in 1870) by dropping small portions of glycol into a mixture of nitric and sulfuric acids cooled to 0º, but A. Kekulé previously (1869) nitrated ethylene and obtd an unstable oil which he presumed to be Glycol Nitrite-Nitrate but which in 1920 was shown by Wieland & Sakellarios to be a mixture of EGDN and the nitric ester of β-Nitroethyl Alcohol (quoted from Ref 5, p 1195 and from Refs 1, 6 & 7). Other investigators preparing NGc before publication in 1926 of Rinkenbach's work (Ref 5) included: Champion (1871), Neff (1899) & Wieland & Sakellarios (1920) (quoted from Ref 5) and also Dautriche (Ref 2), Hough (Ref 3) & Oehme (Ref 4). Rinkenbach (Ref 5, p 1195) prep'd EGDN by nitrating purified glycol obtd by fractionating the commercial product under pressure of 400mm Hg and at temp 120º (See Ref 2, under Ethylene glycol, p 678). For this 20g of middle fraction of purified glycol was gradually added to a mixt of 70g nitric acid (d 1.42) and 130g of sulfuric acid (d 1.84), maintaining the temp at 23º. The resulting 49g of crude product was washed with 300ml of w (in small portions) to obtain 39.6g of purified product. The low yield so obtd could be improved by maintaining a lower temp and using a different nitrating acid mixture.

In the book of Naoum (Ref 7) are described several laboratory and industrial methods for prep of EGDN, such as:

1) Direct Nitrination of Glycol is carried out in
exactly the same manner, with the same apparatus and with the same mixed acids as in the nitration of glycerine, such as described on pp 25-75 of Naoum. A brief description for prep of NGc is given in Vol 5, under Dynamite, p D1590. In the test nitration of anhydrous glycol (100g) with 625g of mixed acid (HNO₃ 40 & H₂SO₄ 60%) at 10-12°, the yield was 222g and it dropped to 218g when the temp was raised to 29-30°. When 500g of mixed acid (HNO₃ 50 & H₂SO₄ 50%) was used at 10-12°, the yield increased to 229g. In commercial nitration, the maximum yields obtd from 100kg anhydrous glycol and 625kg of mixed acid contg HNO₃ 41, H₂SO₄ 58 & water 1% were 222.2kg NGc at nitrating temp of 10-12° and only 213.2kg at 29-30°. This means 90.6% of theory, as compared to 93.6% with NG. Better results (229kg of NGc or 93.4% of theory) obtd on nitrating with 500kg of acid contg HNO₃ 50 & H₂SO₄ 50% at 10-12° (Ref 7, p 219).

2) Direct Production of NGc from Gaseous Ethylene. This method was introduced after WWI by the Chemische Fabrik Kalk, GmbH in Köln-Kalk by Dr. H. Oehme and later patented in the USA (Ref 4). Accdg to description given in Ref 7, pp 220-22, the direct action of mixed acid on gaseous ethylene is similar to the method proposed by Kekulé in 1866 and mentioned above. The action of mixed acid on ethylene can be represented as follows:

\[ \text{CH}_2 = \text{HNO}_3 \rightarrow \text{CH}_2\text{NO}_2 \text{HNO}_3 \rightarrow \text{CH}_2\text{NO}_2 \text{HNO}_3 \rightarrow \text{CH}_2\text{NO}_2 \]

Ethyl- | Nitroethyl | Nitroethyl

and simultaneous reaction:

\[ \text{CH}_2 - 2\text{HNO}_3 \rightarrow \text{CH}_2\text{ONO}_2 \text{HNO}_3 \rightarrow \text{CH}_2\text{ONO}_2 \text{HNO}_3 \rightarrow \text{CH}_2\text{ONO}_2 + \text{HNO}_3 \]

Ethyl- | Glycol | Nitrato

This 2nd reaction, in which a 3rd mole of nitric acid drives out the nitrous acid, explains the rather high content of nitrogen oxides in the spent acid. This mixture of 40-50% Nitroethyl Nitrato & 40-50% Nitroglycol is known as "Kekulé Oil". As its N content is up to 19.5%, which is even higher than for NGc, it is a highly brisant expl. Accdg to GerP 310789 of 1918, such oil can be formed when a current of dry ethylene is passed thru an anhydrous mixed acid contg 32% HNO₃. The yield is 70% of the theoretical calc'd on amt of ethylene used. After washing the oil with hot w, it can be converted directly into a Dynamite by taking it up in absorbents like Kieselguhr or gelatinized with NC to form Gelatindynamite. Direct separation of the oil from the spent acid accounts for only two-thirds of the total oil. The spent acids still contain 8 to 10% of the total oil, which can be separated by extraction with chloroform or ethylenecarbonate. This residual oil is unstable.

Acq'd to GerP 386687 of 1923, the neutralization of crude oil after washing with hot w is done with neutral Na sulfite, in order to avoid the formation of emulsions which occur when strong alkalies are used.

A simple method of separating NGc from Kekulé Oil was described in GerP 384107 of 1923. Here the oil was slowly distilled with steam or better digested with w at 80-90°, until the Nitroethyl Nitrato it contained was almost completely converted into products sol in w. The undissolved portion was separated and neutralized. It consisted of almost pure NGc. From 100 parts of crude oil about 40 parts of NGc were obtd. The economy of the process depended upon a cheap source of ethylene and upon the possibility of recovering valuable by-products from the destroyed Nitroethyl Nitrato (Ref 7, pp 220-22).

3) Preparation of NGc from Ethylene Oxide. Accdg to GerP 376000 of 1920, ethylene oxide (qW) was passed into cond nitric acid, and after saturating the latter with the gas, the cond sulfuric acid was added. The resulting oily substance, separated from spent acid contained at least 16% of N. It consisted mostly of NGc and polymerization products of nitroethylene oxide. The crude oil could be stabilized by treatment with steam or hot w, as described in GerP 377268 of 1920, listed in Ref 7, p 223.

4) Preparation of NGc by Method of Messing (Ref 18b) from ethylene thru chlorohydrin & ethylene oxide:

\[ 2\text{CH}_2 = \text{CH}_2 - 2\text{HCl} \rightarrow 2\text{Cl} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{OH} \rightarrow \text{Ca(OH)}_2 \]

\[ 2\text{CH}_2 = \text{CH}_2 \cdot \text{O} + \text{CaCl}_2 + 2\text{H}_2\text{O} \]
After separating the oxide it was converted to ethyleneglycol by heating with water and then nitrated with mixed acid 5) Preparation of NGc by duPont Method, in which formaldehyde is reacted with carbon monoxide and water to form glycolic acid: HCHO + CO + H2O = HO.CH2-COOH and after esterification of the acid with methanol, the resulting methylglycolate was reduced to form methanol & glycol: HO.CH2-COOCH3 + 2H2 = CH3OH + HO.CH2.CH2OH After separating glycol it was nitrated by mixed acid

EGDN (NGc) was first commercially introduced in 1926 in the USA by Union Carbide Chemical Corp. Original mixture employed in Dynamites contd 20% NGc & 80% NG, but later mixts contd as much as 80% of NG were used. This has been brought about by the reduction in price to below the cost of NG

Prepn of EGDN and of other nitrated glycols was described by Auberttn (Ref 17c). The yield of EGDN was 93% of theory

Continuous methods using the same installations as for manuf of NG are used now in Europe. Two of these installations, Schmid-Meissner and Biazzi, are described in Vol 3 of Encycl, pp C502–C504. We also know that continuous method of Schmid-Meissner is installed in Argentina at the Naval Explosives Plant. The same plant employs Bofors Continuous Method for manuf of TNT. Accdg to Ref 24, nearly 100% conversion of Gc to NGc is achieved by mixed acid nitration in liquid sulfur dioxide

Note: Rinkenbach & Aronsen (Ref A) measured the yield of Diethylene Glycolinitrate as a function of the ratio of sulfuric acid to the amount of water present when nitration was complete, holding the nitric acid in a constant excess. They found that a value of 3.15 gave the maximum yield, about 83%, and reasoned that more conc sulfuric acid dehydrated the DEGC to form poly EGC's which gave lesser yields of dinitrates

Properties and uses of EGDN (Refs 1, 2, 5, 6, 6a, 7, 7a, 8, 9, 10, 11, 12, 12a, 13, 14, 15, 16, 16a, 17, 17a, 18, 18a, 18b, 18c, 19, 19a, 20, 21 & 23):

Aging Properties of Explosives Containing NGc. See under Uses of NGc

Brisance by Lead Block Compression (Hess Crusher Test) – 30.0mm, vs 18.5mm for NG and 15mm for TNT (Ref 7, p 157 under Nitroglycerine as an Explosive)

Brisance by Sand Test, detd in mixts with 40% kieselguhr, gave for NGc mixts sl higher results than with those contg NG (Ref 19, p 133)

Chemical Properties. On heating with eq solns of alkali, gradual soln with saponification, similar to NG, takes place. With alc KOH, NGc reacts violently with formation of K nitrate and glycolate (Ref 7, p 224)

Chemical Stability. See Stability

Chemical Test for Purity is conducted by Nitrometer Method, originated by Lange but modified by duPont Co. Detailed description of the test is given in Vol 1 of Encycl, under "AMMONIUM NITRATE, Gasometric Method", pp A373–A378. N content of NGc should be about 18.42%, vs 18.50 for NG

Critical Temperature – 114–116° (Ref 5, p 1200)

Crusher Test. See under Brisance

Decomposition (or Explosion) Equation:

C3H6(NO3)2 + 2CO2 + 2H2O + N2. It is an ideal decomp equation because there is enough oxygen for complete combn. Corresponding equation for NG is:

4C3H6(NO3)2 = 12CO2 + 10H2O + 6N2 + O2

Equation given by Kast for NG (Ref 7, p 146, Footnote 21):

wherethin the formation of NO to a slight extent as an endothermic side reaction is assumed

Detonation Velocity of liquid NGc, detd in glass tubes 1 cm in diam with 1 mm wall thickness 2050m/sec and 7300m/sec at d 1.485.

For liq NG detd in glass tube 0.39 inch diam and d 1.6 1600–1900m/sec, whereas in steel tube 1.25 inch diam it was 7700m/sec at d 1.6 (Ref 23, p 233). Curme & Johnston (Ref 19, p 132) give 8266m/sec, vs 8484 for NG, when using No 8 cap and PA booster

Energy Content. Comparing the heat of expln, 1705.3cal/g at C_V and water liquid with that for NG (1595.0cal/g), Naoum (Ref 7, p 225) stated that the energy content of NGc is ca 107% that of NG

Energy in Meter-Kilograms Developed on Explosion of 1 Kg of Material: 695.7 x 10^6 for NGc vs 647.8 x 10^6 for NG (Ref 6, p 298 & Ref 19, p 132)

Explosion Reaction. See Decomposition Equation

Explosion Strength or Power. As regards energy content and high deton velocity, NGc occupies first place by the customary methods
for detg explosive strength. If Lead Block Expansion (Trauzl Test) of 10g NGc with water tamping is 600cc, vs 590cc for NG, the strength of NGc is 110% that of NG, whereas its en ergy content is 107% of NG (Ref 7, pp 226–27). Blatt (Ref 16) gave 170% of PA Explosion Temperature: 257° in 5 secs (Ref 23, p 143), vs 222° for NG (Ref 23, p 233). Accdg to Wieland & Sakellarios (Ref 3a and quoted in Ref 5, p 1199) NGc can explode at as low as 215° when rapidly heated, and this remp is listed in Ref 19, p 132 (Comp with Temperature of Explosion)

Flame Temperature – 1350°C (Ref 12b) Flammability (Inflammability). Accdg to Ref 7, p 225, both NGc and expls contg it ignite when in contact with a flame, and bum with a sputtering unless a sudden overheating occurs, in which case there is an expln. This behavior is similar to that of NG. In general NGc expls bum more quietly than do those contg NG, and have less tendency to explode than the latter Fluidity at 20° – 27.54 at sp gr 1.4853 vs 3.47 for NG at sp gr 1.587 and water 100.0 (Ref 5, p 1498)

Gas Volume Produced on Explosion of 1 Kilogram – 736.93 liters at 0° & 760mm Hg, vs 715.53 for NG (Ref 6, p 298 & Ref 19, p 132) Gas Volume Produced on Explosion of 1 kg, calc'd to temp of expln 4209°, 12099 liters vs 11663 liters for NG at 4177° (Ref 19, p 132) Gelatinizing Power. NGc gelatinizes NGc's much faster than does NG. Gelatinization takes place in a short time even at low temps, while with NG heat must be applied (Ref 7, p 224 & Ref 15, p 226)

Heat of Combustion at Cv – 1763.9cal/g or 268.22kcal/mole, vs 1630.4 & 370.5 for NG (Ref 5, p 1498, Ref 6, p 298 & Ref 19, p 132) Heat of Combustion at Cp – 1752.5cal/g or 266.48kcal/mole, vs 1622.1 or 368.36 for NG (Ref 5, p 1498 & Ref 19, p 132)

Heat of Explosion at Cp, with water liquid 1705.3cal/g and 1580.9cal/g with water gas (Ref 7, p 225), vs 1589cal/g and 1470, respectively for NG (Ref 7, p 148) Heat of Formation – 55.58kcal/mole or 365.5 cal/g, vs 81.7 or 359.8 respectively for NG (Ref 5, p 1199). Naoum (Ref 7, p 225) calcd for NG 67.7kcal/mole; 365.5cal/g listed in Ref 19, p 132

Hygroscopicity. Pure NGc is practically nonhygroscopic, in which property it does not differ from NG. Samples kept in an air space saturated with water-vapor at 26° over a period of 15 days and weighed regularly not only failed to absorb moisture but lost some weight. A sample of pure NG under the same conditions did not appreciably increase or decrease in wt (Ref 5, p 1199) Impact Sensitiveness or Sensitiveness to Shock. It is less sensitive than NG. Tests made on the small ButMines Apparatus, using 500g weight gave the following values for the minimum fall: NGc 110cm and NG 70 (Ref 5, p 1200). Naoum (Ref 7, p 225) gives 20–25cm for NGc, vs 8–10cm for NG for deton of samples absorbed on filter paper when using Kast Apparatus with 2kg weight. The same values are given in Blatt (Ref 16) and in addition he gives FI = 20% PA. In AMCP 706–177 (Ref 23) are given results of tests with PicArsnApp using 1 pound weight and 20mg samples – 4 inches for NGc (p 143), vs 1 inch for NG (p 233)

Inflammability. See Flammability

Initiation Sensitiveness. NGc is very sensitive to initial impulse, and NG is exploded, both in a liquid condition and as in Dynamite by the weakest common cap, a No 1, even without confinement (Ref 7, p 226 & Ref 16) Magnetic Rotation at 12.6°: specific gravity 0.6686 & molecular rotation 3.7681 (Ref 5, p 1200 & Ref 19, p 132)

Physiological Properties. See under Toxicity Power. See under Explosive Strength Pressure Developed on Explosion of One Kilogram in One Liter – 12498kg/cm² for NGc vs 12048 for NG (Ref 6, p 298; Ref 19, p 132) Reaction on Explosion. See Decomposition (or Explosion) Equation

Sand Test for Brisance. See under Brisance by Sand Test Sensitiveness to Impact (or Shock). See Impact Sensitiveness Sensitiveness to Initiation. See Initiation Sensitiveness

Solubilities of NGc. At ordinary temps NGc is readily sol in alc, ether, acetone, chl, benz, NB and isluene, but only sl sol in CCl₄ and benzine. The solubility relations of NGc are not essentially different from those of NG, aside from its soly in water. The following amounts of NGc are dissolved in 1 liter of w: 6.2g at 15°, 6.8 at 20° and 9.2 at 50°; vs
1.6, 1.8 and 2.5, respectively, for NG (Ref 5, p 1199 and Ref 7, pp 224 & 119). Aubertin (Ref 17e) gives 0.50g in 100g of w at 25°; soly of w in 100g NGC - 0.43g

Solubility Effects. Inasmuch as soly of NGC in w is much higher than that of NG, it is expected that a lower yield will be obtd in the course of manuf. However, the possibility of nitrating and washing at low temps offers a method of decreasing this loss (Ref 6, p 299) Specific Heat at RT - approx 0.4cal/g for liquid or gelatinized (detd by G. Clift) Stability by Abel Test at 72°. NGC colors KI paper quickly. However, this should be attributed to the relatively high evaporation rate and slight dissociation of the vapors, and does not represent a low chemical stability (Ref 7, p 226)

Stability at 75°. On long continued heating in a loosely covered weighing dish, NGC showed greater stability than did NG (Ref 7, p 226). On p 135 of Ref 7 is Table 4, which shows that after heating for 12 days at 75° only 4.2% of NGC began to decompose (becoming acidic), vs 28.0% NG. The corresponding values for after 18 days of heating were 35.0% for NGC and 54.0 for NG. Complete decomp took place after 25 days for 71.0% of NGC vs 73.5% of NG

Temperature of Explosion (Not to be confused with Explosion Temperature). Accdg to Rinkenbach (Ref 6, p 298), temp developed on expln of NGC is 4200°C, vs 4177°C for NG. Same tems are listed by Curme & Johnston (Ref 19, p 133)

Toxicity. Accdg to Naom (Ref 7, p 224), NGC causes headache, just like NG, but on account of its volatility its effects on the workmen are more violent than those of NG. In the opinion of Rinkenbach (Ref 6, p 290 and Ref 5, p 1200) the toxic effects produced by NGC are not worse than those of NG and probably are less prolonged. For more detailed description of NGC toxicity, see Curme & Johnston (Ref 19, p 312), E. Gross, M. Bock & F. Helbing, ArchExptlPathPharmakol 200, 271 (1942) and under Ethylene glycol Dinitrate Liquid Propellant for Use in "ADAM" Munition. The munition is classified. See also Ref 18c Vacuum Stability. No information

Vapor Pressure. Accdg to Rinkenbach (Ref 6, p 299) vapor pressure detd in 1926 gave 0.0565mm Hg at 22°, which is about 150 times as great as that of NG. Curme & Johnston (Ref 19, p 132) gave at 20° 0.0490mm for NGC, vs 0.00038 for NG and at 50° the values are 0.665 and 0.0081, respectively. Jordan (Ref 19b) gave for NGC: 0.02330mm at 15°, 0.07059 at 25°, 0.2150 at 35°, 0.44250 at 45°, 0.9619 at 55°, Naom (Ref 7, p 109) gave for NG: 0.00025mm Hg at 20°, 0.00083 at 30°, 0.0024 at 40°, 0.0072 at 50°, 0.0188 at 60°, 0.043 at 70°, 0.098 at 80° and 0.29mm at 93.3°

Velocity of Detonation. See Detonation Velocity

Viscosity. NGC is considerably less viscous than NG. At RT about 8 times as fluid as NG (Ref 6, p 298). The time taken for 5cc to run out of a 10ml pipet was 4.8sec for water, 5.0sec for NGC & 12.5sec for NG. If viscosity of water is designated as 100 then 111 is for NGC and 278 for NG (Ref 7, p 223). Rinkenbach (Ref 5, p 1498) gave at 20° 0.0363 for NGC vs 0.288 poises for NG. Viscosity detd at PicArsn Lab was 4.2 centipoises at 20°. Curme & Johnston (Ref 19, p 132) gave at 20° 0.0421 poises for NGC, vs 0.360 for NG, while at 50°, the values were 0.0214 & 0.0938, respectively

Volatility. NGC is appreciably volatile even at ordinary temperatures and considerably at elevated temps. Naom (Ref 7, p 223) gives the following values representing the loss in weight of a 15g sample in an open dish 65mm diam & 40mm high:

1) At 20° after 24hrs 0.14%; 48 hrs 0.37; 7 days 1.63; 12 days 2.06; 30 days 6.91 and 6 months 47.0%
2) At 35° after 24 hrs 3.6%; 48 hrs 8.1; 7 days 21.7; 12 days 46.6; 20 days 68.5 and 40 days 100%

For comparison with NG, the following values are given by Naom (Ref 7, p 109): 20g of NG in an open dish of 70mm diam lost in 24 hrs: at 50° 0.2%, at 75° 1.6 and at 100° 10%

Uses of Ethylene glycol Dinitrate

Although known since 1870 to be an expl, it found no practical application because it was too expensive. It was not until 1904 that a patent (DRP 179789) covering its use as an expl was granted, but it was about 8 years before its actual use in expl comps was recorded by Dautrieche (Ref 2). The use of NGC on a large scale, as an antifreeze addition to expls based on NG (Dynamites), took place when inexpensive methods of manuf of glycol
were developed, such as the method of Hough, patented in 1916 (Ref 3). Straight NGc was used in Germany during WWI as replacement for NG which was in short supply (Synthetic method of manufacture of glycerin was not invented until later).

Studies at US Bur. Mines by Perrott & Tiffany (Ref 6b) have shown that properties of expls contg mixts of NG with up to 25% NGc did not differ (except fr p) from those contg straight NG. Studies by Coates & Perrott (Ref 7a) of ageing properties of Gelatin Dynamites have shown that propulsive strength is unaffected by age by both NGc and NG types, but deton velocities of NGc contg Dynamites have shown better ageing properties than those contg NG alone (quoted from Ref 19, p 133).

Compositions and properties of Dynamites contg NGc are given in Vol 5, under DYNAMITE, pp D1590-R to D1592 (See also Ageing of Dynamites in Vol 1 of Encycl., pp A110-R to A112-L).

EGDN was used by Germans during WWII in some propmts. For example, their Ersatzpulver R61 contd 35.5% of EGDN. Its compn is given in Vol 5 of Encycl., p E17-R.

The following plastic compmt contg EGDN, patented by WASAG-Chemie AG, Essen (DAS 1148924) are described in Ref 22b: 1) EGDN 38.0, CC (collodion cotton) 0.75, Lackwolle "E33" (in 33% soln of butyl acetate) 0.75, liquid DNT/TNT (probably like Tropföl= Dripoil) 2.0, TNT 2.0, AN 52.3, woodmeal 4.0 and iron oxide 0.2%. 2) EGDN 34.7, CC 0.8, Lackwolle "E33" (in 33% soln of butyl acetate) 0.8, DNT with TNT 4.5, AN 49.2, woodmeal 2.0 and iron oxide 8.0%. 

**NOTE:** Thru the courtesy of Dr W. Schmacker (German civilian assigned to Picatinny Arsenal under the International Professional Scientists Exchange Program) the following info was obtd from WASAG-Chemie GmbH, West Germany by letter dated 24 July 1973:

**Lackwolle E33** is a pressure-cooked modified collodion cotton of 12.0 to 12.2% N. Its stability is less than 2.5 cc NO/g and its viscosity by falling ball method of a 33% soln in 90-100% butyl acetate soln is 160 sec or by Hercules method 15-18 centipoises.

The following liquid propellant based on EGDN was recently developed in the USA: EGDN 87.1±1.2, NPL(1-Nitro-2-propanol) 12.0±1.0 and 2-NDPhA(2-Nitrodiphenylamine) 0.9±0.1%. Its intended use is in "ADAM", which is one of the classified items of munition.

A proposed specification for this liquid propellant is described after the description of analytical procedures for EGDN.

No US Military Specification for EGDN exists.

**Refs for EGDN:**

"Vapor Pressure of Organic Compounds", Interscience, NY (1954), Chap 7
20) Yaremchenko & Svetlov (1957), 178-79
21) Gius, Trattato VI (1959), pp 124-27
22) Cond-ChemDict (1961) - not listed
22a) V. Öhman et al, Explosivst 1961, 5 & 95-113
(Stability of acidic NGc system)
22b) H. Joachim & H. Schüter, Explosivstoffe 1964, 14
22c) Urbaniski 2 (1965), 142-49
24) Stamicarbon N.V., NethPAppl 6512732 (1967) & CA 67, 731435 (1967)
25) Y. Morikawa, Nature 213 (5078), 841-2 (1967) (Toxicology)
26) CA 66, 84426 (1967)
31) R.J.M. Fraser & N.C. Paul, JCS, B 66 (8), 659-63 (Mass spectrum) & CA 69, 31418 (1968)
32) J.E. Evendijk, Explosivst 1968, 16 (7), 152-4 (Analysis) & CA 69, 98116 (1968)
33a) Sax, 3rd ed (1968), 747
34) A. Dravnieks & M.J. Salkowski, USP 3430482 (1969) (Detection in air) & CA 70, 89339 (1969)
35) T. Matsushita, IndHealth (Kawasaki, Japan) 1969, 7 (1-2), 22-30 (Toxicology) & CA 72, 82682 (1970)
37) A. Dravnieks & J. Fischman, USP 3568411 (1971) (Detection in air) & CA 74, 128367 (1971)

Addit Refs for EGDN:
A) W.H. Rinkenbach & H.A. Aaronson, IEC 23, 160-1 (1931)
(Deton vet and small bubbles) & CA 42, 369(1948)
D) L. Médard, MP 31, 131-43 (1949) (Shock sensitivity, many other expls) & CA 46, 11685 (1952)
E) J. Boileau & M. Thomas, MP 33, 155-7 (1951) (Visc, sp gr, nD) & CA 47, 5200 (1953)
F) R. Steinberger et al, JACS 77, 4748-50 (1955) (Burning rate) & CA 50, 3043 (1956)
H) N.A.P. Nilsson, USP 2735722 (1956)
(Manuf, and other compds) & CA 50, 6796 (1956)
I) K.K. Andreev & B.S. Samsonov, Nauch-Doklady VysshShkol'ny, KhimKhimTekhnol 1958, No 2, 229-32 (Effect of pressure on heat sensitivity, also NG) & CA 52, 17713 (1958)
K) B.B. Coldwell, Analyst 84, 665-7 (1959) (Detection, other compds) & CA 54, 17887 (1960)
N) P.V. Öhman et al, Explosivst 9, 95-113 (1961) (Manuf safety) & CA 56, 6229 (1962)
O) H. Yoshikawa & M. Ishii, BullNatInstHealth(Kawasaki, Japan) No 7, 1-6 (1962)
(Toxicology) & CA 58, 14615 (1963)
Q) T. Akisada, BunsekiKagaku 12, 443-6 (1963) (Analysis) & CA 59, 9235 (1963)
R) P. Carmichael & J. Lieben, ArchEnvironHealth 7(4), 424-39 (1963) (Toxicology) & CA 60, 2245 (1964)
S) C. Einert et al, AmIndHygAssoc 24(5), 435-47 (1963) (Toxicology) & CA 60, 3413 (1964)
T) K. Hotla & R. Yamada, InternArchGewerbepatholGewerbehv 20, 311-15 (1963) (Toxicology) & CA 60, 8540 (1964)
U) G. Krien, Explosivst 11(10), 207-9 (1963) (Analysis) & CA 61, 11839 (1964)
X) L. Parmeggiani et al, MedLavoro 55(1), 23-40 (1964) (Toxicology) & CA 61, 3600 (1964)
Test procedures (not specifications) are essentially those of MIL-N-246B, 19 Feb 1962, covering Nitroglycerin with the modifications described under 4.3 TEST METHODS AND PROCEDURES which follow.

4.3 TEST METHODS AND PROCEDURES

4.3.1 Determination of Moisture in EGDN by Karl Fischer. Weigh accurately a 5–10g portion of the sample (sample size shall be in accordance with the strength of the Karl Fischer reagent) of the EGDN into a tared narrow-necked stoppered flask. Titrate directly until a brown tinge persists in the soln for 30 seconds (Potentiometric endpoint indicators may also be used in titration with Karl Fischer reagent). Calculate as follows:

\[
\text{Percentage moisture} = \frac{100 \times (\text{KF})}{W}
\]

where: \( K \) = ml of Karl Fischer reagent used in titration
\( F \) = Reagent factor (g of water per ml of reagent)
\( W \) = Weight of sample in grams

Note: A detailed description of Karl Fischer Method is given in Vol 5 of Encycl, pp D1622 to D1627. It is practically the same as Method 101.4 of MIL-STD-650.

4.3.2 Determination of Acidity or Alkalinity. By means of a pipette, transfer a portion of approx 10g of the sample to a tared 250-ml beaker, reweigh and dissolve in 100ml of benzene. Move the soln to a 250-ml separatory funnel and shake the contents of it with a 50-ml portion of neutral distilled water. After separation of layers run the water layer into the above 250-ml beaker. Repeat the operation using another 50ml of distilled and transfer the bottom layer to the same beaker. Add to beaker several drops of bromemethyl blue indicator. If the soln turns yellow titrate imme-

The specification of Trojan-US Powder for EGDN (without stabilizer) is as follows:

| Assay by Nitrometer | 98.0%, min |
| Acidity as HNO₃ | 0.01%, max |
| or | Alkalinity as Na₂CO₃ | 0.01%, max |
| Moisture by Karl Fischer | 0.25%, max |
| KI Test at 82.2°C | 8 minutes, min |

Percentage Nitric Acid = \( \frac{6.3(V-v)N}{W} \)

where: \( V \) = ml NaOH soln required for sample
\( v \) = ml NaOH soln required for blank
\[ \text{Percentage of Na}_2\text{CO}_3 = \frac{5.3(V - v)N}{W} \]

where: \(V\) = ml sulfuric acid soln required for sample
\(v\) = ml sulfuric acid soln required for blank
\(N\) = Normality of sulfuric acid soln
\(W\) = Weight of sample

4.3.3 Determination of Nitrogen (Assay by Nitrometer).

According to W. J. Carmill, EGDN is dried at Trojan laboratory by desiccation prior to nitrogen determination, thus eliminating the filtering steps described in 4.3.3.2 and 4.3.3.3 of MIL-N-246B. Since moisture content of the resulting sample is less than 0.03\% no correction is made for this negligible amount, and the calculation thus becomes:

\[ \text{Percentage of Nitrogen} = \frac{A}{W} \]

where: \(A\) = Reading of the mercury level on the measuring tube
\(W\) = Weight of sample in grams

4.3.3.1 Standardization of Nitrometer. Standardization of the DuPont 5-part form of Lange's nitrometer, or equal, shall be made by Method 209.3 of Military Standard MIL-STD-286

Note: A detailed description of standardization and tests with nitrometer are given in Vol 1 of Encycl, pp A373 to A376 with a drawing of nitrometer on p A374-L

4.3.3.2 Not used for EGDN

4.3.3.3 Procedure. Eliminate the part dealing with filtering thru filter paper and start as follows:

Transfer from a moisture-proof receptacle contg EGDN dried in desiccator, 0.70 to 0.75g sample (contg less than 0.03\% moisture) to a tared 25-ml beaker and weigh accurately immediately. Add 5ml of glacial acetic acid and stir the mixture with a small glass rod until the EGDN has dissolved. With the aid of this rod, transfer the soln quickly to the cup of the generating bulb, making certain that no air is drawn into the generating bulb. Measure 25ml of sulfuric acid (94.5\%\(\text{H}_2\text{SO}_4\)) into a graduate. Then rinse the beaker and glass rod by means of successive 5-ml portions of this acid, transferring each portion of the rinsing to the generating bulb cup. Follow this by stirring the acid in the cup with glass rod and draw the rinsing into the bulb. Any air drawn into the bulb shall be forced out and the upper stopcock closed when the sample has been completely drawn into the generating bulb

Caution: The lower stopcock must remain open and the mercury reservoir adjusted so that the level of the mercury in the reservoir is 13 to 15 inches below the level of the mercury in the generating bulb. The generating bulb shall be wrapped in a strong towel to prevent injury to hands and body, on accidental breaking of bulb, by glass splinters and acid during shaking operation.

With the lower stopcock open and upper stopcock closed, shake gently the generating bulb while keeping its lower end in a fixed position until most of the gas has been generated. Adjust the mercury reservoir so that the mercury in the generating bulb drops nearly to the lower shoulder, and then close the lower stopcock. Shake vigorously for 3 minutes, place the bulb on the rack and allow to stand for 3 minutes. Remove the bulb from the rack, shake for additional 3 minutes and replace on the rack for 3 minutes. After repeating the above procedure once more, transfer the generated gas thru upper stopcock to the measuring and compensating tubes adjusted until the level in compensating tube is approx at the standardization mark. A levelling device shall be used which will make possible accurate adjustment of the levels. Note the reading on the measuring tube and calculate the percentage of nitrogen of the sample by the equation indicated above. It should be not lower than 98\% of 18.42\%.

4.3.3.4 Determination of Stability by KI Test. Filter a portion of EGDN sample thru two thicknesses "S and S" Number 604 filter paper or equivalent. Transfer a 2ml portion of filtered material, by means of a pipette, to each of three test tubes which are 5.5 inches long, 0.50 inch internal diameter and 0.62 inch outside diameter (Care should be taken during transfer not to leave droplets of the EGDN on the sides of the test tubes). Stopper each tube by means of a new tightly fitting cork thru which passes a tightly fitted glass rod equipped with a platinum hook for a strip of standard KI-starch indicator paper, about
1 inch long and 3/8 inch wide. Dip a small diameter glass rod into a 50% soln (by volume) of pure glycerin in distilled water, and as the rod is withdrawn, contact is made with the sides of container so as to minimize the amount of liquid adhering to the rod. Draw the moistened rod across the upper part of paper so as to produce a level and distinct line of demarcation on lower edge of the wet upper area. Prepare a blank by suspending a moistened strip of standard KI-Starch test paper in a clean dry test tube.

Adjust the temperature of the heat tube bath to 82.2°C±1°C and insert all four test tubes into the heating soln. The depth of immersion should be appx 2 inches. Place the bath in such a position that the test tubes are viewed against a white background illuminated by bright diffused daylight. Note the time of insertion of the tubes into the bath. During the test the line of demarcation on the test paper strip should be 3 inches above the EGDN level in the test tube. The line of demarcation in the blank tube is regulated at an equivalent height of the tube. Consider the end point of test to be the first appearance of any discoloration at the line of demarcation between the wet and the dry portion of the test paper in the sample tube. This discoloration should be in excess of discoloration observed at the same position on the test paper in the blank. Note the time for completion of the test to the nearest minute. Consider the minimum time for the three tubes to represent the heat test value of the sample.

After the test, rinse all rods and tubes with acetone to remove EGDN, followed with warm soapy water and then with large amt of tap water and finally with distilled water. Dry everything in an oven at approx 80°C.

**Table Et 5 — Refractive Indices of Pure Compounds**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Ethylene Glycol Dinitrate</th>
<th>Diethylene Glycol Dinitrate</th>
<th>70% Nitroglycerin</th>
<th>30% Nitrotoly glycerin</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0</td>
<td>1.4751</td>
<td>1.4491</td>
<td>1.4536</td>
<td>1.4767</td>
</tr>
<tr>
<td>20.0</td>
<td>1.4732</td>
<td>1.4472</td>
<td>1.4517</td>
<td>1.4748</td>
</tr>
<tr>
<td>25.0</td>
<td>1.4713</td>
<td>1.4454</td>
<td>1.4498</td>
<td>1.4728</td>
</tr>
<tr>
<td>30.0</td>
<td>1.4693</td>
<td>1.4435</td>
<td>1.4479</td>
<td>1.4709</td>
</tr>
</tbody>
</table>

Inspection shows that the refractive indices of nitrates of the glycols are practically identical and much lower than those of Nitroglycerin and the Nitroglycerin-Nitrotoly glycerin mixture. Determination of the refractive index of a sample should give at least a qualitative indication of the presence of the glycol compounds.

**Tests with Mixtures:**

In order to make this method quantitative mixtures of Nitroglycerin and Ethylene glycol Dinitrate were made up from accurately weighed portions of each and studied in the same manner as were the pure compounds. The curves derived gave the values in Table Et6.

Concentration-refractive index curves at 15°C, 20°C, and 25°C were plotted from these values. It was found that the points were uniformly below a straight line joining the values for the pure compounds at the given temperature. From the average curve drawn from each temperature the values in Table Et7 were read off.
Table Et6 – Refractive Indices of Mixtures of Ethyleneglycol Dinitrate and Nitroglycerin

<table>
<thead>
<tr>
<th>Percent EGDN</th>
<th>33.71</th>
<th>49.17</th>
<th>61.93</th>
<th>79.23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent NG</td>
<td>62.65</td>
<td>66.29</td>
<td>50.83</td>
<td>38.07</td>
</tr>
<tr>
<td>n&lt;sub&gt;18&lt;/sub&gt;&lt;sup&gt;D&lt;/sup&gt;</td>
<td>1.4704</td>
<td>1.4651</td>
<td>1.4617</td>
<td>1.4581</td>
</tr>
<tr>
<td>n&lt;sub&gt;20&lt;/sub&gt;&lt;sup&gt;D&lt;/sup&gt;</td>
<td>1.4685</td>
<td>1.4634</td>
<td>1.4597</td>
<td>1.4562</td>
</tr>
<tr>
<td>n&lt;sub&gt;25&lt;/sub&gt;&lt;sup&gt;D&lt;/sup&gt;</td>
<td>1.4666</td>
<td>1.4617</td>
<td>1.4577</td>
<td>1.4543</td>
</tr>
<tr>
<td>n&lt;sub&gt;D&lt;/sub&gt;</td>
<td>1.4566</td>
<td>1.4600</td>
<td>1.4556</td>
<td>1.4524</td>
</tr>
</tbody>
</table>

Effect of Impurities:

The effect of the presence of a small amount of oily impurity, such as is found in ether extracts of Dynamite, was next investigated. A Dynamite known to contain Nitroglycerin but no Nitropolyglycerin or Ethyleneglycol Dinitrate was extracted with ether in the usual manner. The extract was evaporated until all ether had been driven off under low pressure and a residue consisting of Nitroglycerin and separated oils, fats, and resins were obtained. The Nitroglycerin was separated by filtration at 30°C and studied by means of the refractometer. It was found that if the temperature was lowered to below 20°C, more oils, fats, and resins separated and obscured the field. The Nitroglycerin was then chilled to 0°C, the precipitated oils, fats, and resins were filtered off, and the clear filtrate was studied under the refractometer. The two series of values were used to construct curves from which values at regular temperature intervals were read off (Table Et8). For purposes of comparison corresponding values for pure Nitroglycerin are given.

Table Et7 – Effect of Varying Proportions on Refractive Indices of Mixtures of Ethyleneglycol Dinitrate and Nitroglycerin

<table>
<thead>
<tr>
<th>Ethyleneglycol Dinitrate</th>
<th>Nitroglycerin</th>
<th>18&lt;sup&gt;D&lt;/sup&gt;</th>
<th>20&lt;sup&gt;D&lt;/sup&gt;</th>
<th>25&lt;sup&gt;D&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent EGDN</td>
<td>Percent NG</td>
<td>n</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>1.4751</td>
<td>1.4732</td>
<td>1.4713</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>1.4722</td>
<td>1.4703</td>
<td>1.4684</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
<td>1.4694</td>
<td>1.4675</td>
<td>1.4656</td>
</tr>
<tr>
<td>30</td>
<td>70</td>
<td>1.4666</td>
<td>1.4648</td>
<td>1.4628</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
<td>1.4640</td>
<td>1.4621</td>
<td>1.4601</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>1.4613</td>
<td>1.4595</td>
<td>1.4575</td>
</tr>
<tr>
<td>60</td>
<td>40</td>
<td>1.4587</td>
<td>1.4569</td>
<td>1.4548</td>
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<tr>
<td>70</td>
<td>30</td>
<td>1.4562</td>
<td>1.4544</td>
<td>1.4523</td>
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<tr>
<td>80</td>
<td>20</td>
<td>1.4537</td>
<td>1.4520</td>
<td>1.4498</td>
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<tr>
<td>90</td>
<td>10</td>
<td>1.4513</td>
<td>1.4496</td>
<td>1.4476</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>1.4491</td>
<td>1.4472</td>
<td>1.4454</td>
</tr>
</tbody>
</table>

These results show a maximum deviation of ±3 per cent to ethyleneglycol dinitrate, or 0.0008 in refractive index from the straight line connecting the 100 per cent values. They also represent a maximum deviation of ±2 per cent, or 0.0003 from any of the points by which the curves were determined. The values at 15°C came the nearest to giving a smooth curve passing through all points, and this may be considered the optimum temperature at which to work.

The foregoing gives a method by which the proportions of the glycol compounds in admixture with Nitroglycerin or Nitroglycerin and Nitropolyglycerin may be determined with a fair degree of accuracy when the pure components only are present. As such it is particularly applicable to the analysis of nitrated mixtures in plant operation.

Table Et8 – Refractive Indices of Pure and Dynamite Nitroglycerin

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Pure NG Before Freezing</th>
<th>After Freezing</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0</td>
<td>1.4751</td>
<td>1.4838</td>
</tr>
<tr>
<td>20.0</td>
<td>1.4732</td>
<td>1.4819</td>
</tr>
<tr>
<td>25.0</td>
<td>1.4713</td>
<td>1.4804</td>
</tr>
<tr>
<td>30.0</td>
<td>1.4693</td>
<td>1.4781</td>
</tr>
</tbody>
</table>

From this table it is evident that the application of the curves derived for mixtures of the pure compounds to the interpretation of values obtained on Dynamite extractives would give results indicating a proportion of Nitroglycerin much higher than that actually present. It is also apparent that the oils, fats, and resins present in Dynamite extractives cannot be removed entirely by freezing, as was recommended by Marqueyrol & Goutel.
Application of Method

Inasmuch as the oils naturally present in Dynamite "dopes" vary considerably and the types of greases used for graining purposes also vary to some extent, it is improbable that a satisfactory correction for the error caused by the presence of the substances could be devised and applied to a Dynamite extractive.

Accordingly, the application of the method and data given in the case of commercial exploitation must be restricted to the qualitative detection of EGDN (and of DEGDN). To the analysis of mixtures that have not dissolved oils and fats from the other constituents of Dynamite, the method can be applied quantitatively, and so is of value in factory-control work.


DETERMINATION of EGDN in MIXTURES WITH NG by INFRARED METHOD. EGDN is often used in admixture with NG in explosives, as the mixture possesses the generally desirable characteristic of having a lower freezing point than either NG or EGDN alone. As precise methods for the analysis of such mixtures are lacking, a method was developed at Picatinny Arsenal (Ref 5) using infrared spectroscopy.

The method involves making absorbance measurements of 20% solutions of the sample in benzene at the peak of the 9.20 micron band for NG and of a 5% solution of the sample in 2-nitropropane at the peak of the 9.60 micron band for EGDN. The measured absorbances, after correction for solvent and cell absorbance, are used to calculate percentages of NG and EGDN by the method of "Successive approximations", described in Ref 5 and here.

Note: Benzene was selected as a suitable solvent because of its small absorbance at the point of measurement for NG; 2-nitropropane was selected as a suitable solvent because of its small absorbance at the point of measurement for EGDN. In addition, the two solvents were selected because they readily dissolve both NG and EGDN. Both solvents were pretreated with anhydrous Na2SO4 and NaCl to minimize the tendency to dissolve NaCl cell.

Definition of Terms Used:
Transmittance (T): Ratio of radiant power transmitted by sample to radiant power incident to it.
Absorbance (A): Logarithm to the base 10 of the reciprocal of the transmittance.
Absorptivity (a): Ratio of the absorbance to the product of the concentration and the length of the optical path. (If only one cell is used for all the work, the path length will be constant and can be left out of all calcs without introducing an error. To simplify the calcns, all measurements were made with the same 0.209mm cell. Hence, all the absorptivities were referred to a 0.209mm basis.)

Apparatus: A Beckman, Single Beam Infrared Spectrophotometer, Model IR 2, with rock salt (NaCl) optics was used in accordance with the instruction manual for the instrument. All absorbance measurements were made at the peaks of the bands, using a single NaCl cell of about 0.2 mm thickness previously calibrated by the interference fringe method described in Ref 1 and found to be 0.209 mm in thickness. Condition of measurement are shown in Table E9.

| TABLE E9 |
|-----------------|-----------------|
|                | NG              | EGDN            |
| Wavelength,     | 9.2             | 9.6             |
| microns         |                 |                 |
| Slit, mm        | 0.29            | 0.78            |
| Gain            | 10              | 10              |
| Period Seconds  | 2               | 2               |
| Shutter         | Glass           | Glass           |

Determination of Cell Absorbance and Absorptivity of NG, EGDN, Benzene and 2-Nitropropane.

By means of a 0.2 mm cell filled with a soln of 15% NG in benzene, the peak of a 9.20-micron band was located by very slowly scanning from about 0.05 μm below to about 0.05 μm above 9.20 μm. A 0.2 mm cell filled with a soln of 5% EGDN in 2-nitropropane was similarly used to locate the peak of the 9.60-micron band. This procedure was followed to insure measurement of the maximum absorbance of the two bands.

Two cells, one of 0.2 mm and another of 0.4 mm were calibrated by the method described in Ref 4 and found to be 0.209 mm and 0.419 mm, respectively. These cells were filled with benzene and the total absorbance of each cell was meas-
ured at 9.20 microns. Then the cells were rinsed with 2-nitropropane, filled with it and measured at 9.60 microns. This gave:

Absorptivity of benzene (a) =
\[
\frac{(A_{0.419} - A_{0.209})}{0.419 - 0.209}
\]

Absorptivity of 2-nitropropane (a) =
\[
\frac{(A'_{0.419} - A'_{0.209})}{0.419 - 0.209}
\]

Cell absorbance of 0.209mm cell = A_{0.209}-a,
where A_{0.419} and A_{0.209} are, respectively, the absorbance of the 0.4 and 0.2mm cells filled with benz at 9.20μ and A'_{0.419} and A'_{0.209} absorbances of 0.4 and 0.2mm cells filled with 2-nitropropane at 9.60μ. The values obtd are shown in Table E10

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent Present</th>
<th>Absorptivity (a) at Wavelengths:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.20μ</td>
<td>9.60μ</td>
</tr>
<tr>
<td>NG</td>
<td>0.5</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>4.23</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>4.32</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>4.29</td>
</tr>
<tr>
<td>EGDN</td>
<td>0.5</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>0.89</td>
</tr>
</tbody>
</table>

The absorptivities of NG and EGDN were detd at points corresponding to the maximum absorption of the measured bands. This was done by measuring the absorbance of known solns ranging in concns from 0.5% to 20%. The absorptivities of NG and EGDN were calcd for each soln by applying the following equations:

Absorptivity = \frac{A_{total} - A_{cell}}{A_{solvent}}
Percent of material in soln, expressed as a decimal

where:
A_{total} = Total absorbance of cell filled with soln of solvent and ingredient
A_{cell} = Absorbance of cell at the particular wavelength
A_{solvent} = Absorbance of the solvent at the particular wavelength (calcd by multiplying the absorbivity as listed above, by the percent of solvent in soln). Thus, a 10% benz soln of NG corresponds to 90% benz)

The absorptivities of NG & EGDN obtd in this investigation are listed in Table 1 of Ref 5, reproduced here as Table E11

**TABLE E11**

Absorptivities of NG and EGDN
(Absorbance per 0.209mm)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent Present</th>
<th>Absorptivity (a) at Wavelengths:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.20μ</td>
<td>9.60μ</td>
</tr>
<tr>
<td>NG</td>
<td>0.5</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>4.23</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
<td>4.32</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>4.35</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>4.29</td>
</tr>
<tr>
<td>EGDN</td>
<td>0.5</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>0.87</td>
</tr>
<tr>
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<td>5.0</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>average</td>
<td>0.89</td>
</tr>
</tbody>
</table>

**Determination of ingredients:**

A 5% soln of the sample in 2-nitropropane and 20% soln of the sample in benzene were prepd for the analysis. If, when using these solns, a measurement fell outside of absorbance values 0.19–0.70 (65%–20% transmittance), an addtl soln was used to bring the readings within the limits. (Optimum absorbance values are around 0.43 or 37% transmittance). With the 0.209mm cell, the absorbance of the benz soln was measured at the peak of the 9.20μ band and the absorbance of 2-nitropropane soln at the peak of the 9.60μ band. The percentages of the components were calcd by the method of "successive approximations"
The 1st approximation for NG was as follows:

%NG = \( \frac{A_{\text{total}} - A_{\text{cell}} - A_{\text{solvent}}}{100} \) \\

where:

\( A_{\text{total}} \) = Absorbance at 9.20µ of cell filled with benz soin of sample \\
\( A_{\text{cell}} \) = Absorbance of cell at 9.20µ \\
\( A_{\text{solvent}} \) = Absorbance of benzene at 9.20µ

(This value is obtb by multiplying the absorbivity of benz at 9.20µ by the % of benz in soin, that is, a 20% soin of sample will contain 80% benzene)

\( a \) = Absroptivity of NG at 9.20µ (average value 4.29µ from Table 1)

Note: Though the bands to be measured in the dem of each component are selected so as to keep interference from the other constituent at a minimum, there is some absorbance at each band by the component other than the one for which the measurement was made. Correction had to be made for this interfering absorbance. Since no knowledge as to the amt of each constituent was available when the first approximation of NG was calcld, no accurate correction could be made for EGDN. No such correction was attempted and, as a result, the value obtb for NG was only aproximmate (1st approximation). In calcg for NG, the values obtb were taken as 1/5th of the total value since absorbance measurements were made on 20% soins.

The 2nd approximation for NG was calcld as follows:

%NG = \( \frac{A_{\text{total}} - A_{\text{cell}} - A_{\text{solvent}} + A_{\text{EGDN}}}{100} \)

where:

\( A_{\text{total}} \) = Absorbance at 9.20µ of cell filled with the benz soin of sample \\
\( A_{\text{cell}} \) = Absorbance of cell at 9.20µ \\
\( A_{\text{solvent}} \) = Absorbance of benzene at 9.20µ

(This value was obtb by multiplying the absorbivity of benz at 9.20µ by the %age of benz in soin, that is, a 20% soin of the sample was considered to contain 80% benz) \\
\( A_{\text{EGDN}} \) = Absorbance of 9.20µ due to EGDN

found in the preceding approxima-
tion for NG was 15% in the 20% benz soin, the original mixt contd 15/20th or 75% NG and 25% EGDN. Therefore, in this case, EGDN = (0.25 x 0.20) x 0.89 (Ave from Table 1) = 0.0445

\( a \) = Absroptivity of NG at 9.20µ (Ave value = 4.29 from Table 1)

When the 2nd approximation for NG had been obtb, the procedure for approximation was repeated until the values obtb for NG became constant. These values were multiplied by 5 to obtain the total value for NG in the NG-EGDN mixture.

The 1st approximation for EGDN is as follows:

%EGDN = \( \frac{A'_{\text{total}} - A'_{\text{cell}} - A'_{\text{solvent}} - A'_{\text{NG}}}{100} \)

where:

\( A'_{\text{total}} \) = Absorbance at 9.60µ of cell filled with soin of sample in 2-nitropropane \\
\( A'_{\text{cell}} \) = Absorbance of cell at 9.60µ \\
\( A'_{\text{solvent}} \) = Absorbance of 2-nitropropane at 9.6µ. (This value was obtb by multiplying the absorbivity of 2-nitropropane at 9.6µ by the %age of 2-nitropropane in soin, that is a 5% soin of the sample was considered to contain 95% of 2-nitropropane)

\( A'_{\text{NG}} \) = Absorbance at 9.6µ due to NG, obtb as in the following examples: Assuming that the %age of NG found in the calcn for NG was 15% in the 20% benz soin (or 75% NG in the sample), then for a 5% of 2-nitropropane soin, \( A'_{\text{NG}} = (0.75 x 0.05) x 0.35 \) (Ave from Table 1) = 0.1631

\( a \) = Absroptivity of EGDN at 9.60µ (Ave value 15.03 from Table 1)

In calcg for EGDN, the values obtb were 1/20th of the total value since absorbance measurements were made on 5% soins. When the 1st approximation for EGDN had been obtb, the procedure of approximations were repeated until the values obtb for EGDN became constant. This constant value was multiplied by 20 to obtain the total value for EGDN.

In Table 2 of Ref 5, p9 (not reproduced here) are listed values obtb for eight synthetic mixt of NG & EGDN. Three trials were run for each mixture. Average absolute error (ave found minus ave added) was calcld for NG as 0.18% and for EGDN as 0.14%. Average relative error \( \left( \frac{\text{Absol error x 100}}{\text{Average added}} \right) \) was found for NG 1.7% and for EGDN 1.8%.
For employing an extended examination of explosive oils, it is necessary, accd. to Pierson (Ref 6, pp 1355 & 1362) to obtain about 10g of filtered and dried expl oil. The oil can be obtb. by extracting with ether a suitable amt. of Dynamite placed in a 3-inch Buchar funnel, using a rapid filtering paper. This method is described in Ref 6, p 1355 and in Ref 7, pp D1642-R & D1643-L. If qualitative analysis of this oil indicates the presence of aromatic nitrocompds. or of ingredients like DEGDN or Nitosugar, they must be removed from the expl oil prior to determinations of NG & EGDN. Separation may be accomplished by a chromatographic method (Ref 6, p 1363).

When it is decided that nothing else but NG and NGc remain in the expl oil, it is advisable to determine the amount of NG by Hercules Method D90-3e using periodic acid. This method is described in Ref 7, p D1640-R & D1641. If periodic acid analysis gives less than 90-100% NG, the presence of EGDN is indicated and it can be tentatively estimated as equal to 100-%NG. After this the IR method can be employed.

2) Bull of Society of Applied Spectroscopy 4, (2), Jan 1949 (Nomenclature)
4) F. Pristera, PATR 1821, Applied Spectroscopy, 7, 115(1953)(IR method)
5) W. Huff, M. Halik & F. Pristera, PATR 2472(1957)
6) R.H. Pierson in Std Methods Chem Analysis 2B (1963), 1350-64 (Dynamites)
7) Fedoroff & Sheffield, PATR 2700, Vol 5, (1972), D1639 to D1643

Ethylene glycol Dinitrate Liquid Propellant for Use in the "ADAM" Munition ("ADAM" is classified item).
Composition of propellant: EGDN 87.1 ±1.2, 1-NPL (1-Nitro-2-propanol) 20.0 ±1.0 and 2-DNP (2-Nitrophenylenamine) 0.9 ±0.1%

1.0 Scope. This document covers the requirements and tests for Liquid Propellant of above compo
1.1 Safety. The propellant in bulk form is a secondary HE and must be handled according to safety rules.
1.2 Toxicity. The bulk propellant and the EGDN may cause dilation of blood vessels, headaches, nausea, cyanosis, and reduced blood pressure. Extreme exposures resulting from inhalation, skin contact or ingestion may result in central nervous system de
pression, coma, and respiratory paralysis. Drinking of any quantity of the liquids must be avoided. Alcoholic beverages aggravate the health hazard. Severe headaches after exposure may diminish after development of tolerance. Ventilation should be used to reduce the inhalation hazard. Protective gloves and aprons are helpful in avoiding skin contact and frequent washing with soap and water will minimize skin absorption. Alcohol or other solvents should not be used on the skin. The threshold limit value ceiling is 0.2ppm. No inhalation or skin irritation hazard exists with 1-NPL.

2.0 Applicable Documents:
MIL-STD-109: Inspection, Terms and Definitions
MIL-N-3399B: 2-Nitrophenylenamine
There are no Specs for Ethylene glycol Dinitrate

Requirements and Tests for the Above EGDN Liquid Propellant described in Proposed Specification (Code Ident No 19203), attached to the letter of October 5, 1972 of Mr. D.E. Seeger (Chief, Explosives Application Section ADED) to Mr. Frank Paistern (Chief, Instr Anal Res Sec, FRL), both at Picatinny Arsenal, Dover, NJ

3.0 Requirements
3.1 Product Acceptance. Propellant furnished accd to this document shall be inspected for quality in accordance with qualification and acceptance inspection requirements, outlined under Quality Assurance Provisions, items 4.1, 4.1.1, 4.1.2 and 4.1.3 (not included in our description)
3.2 1-Nitro-2-propanol (NPL). Suggested source: (Commercial Solvents Corp, Terre Haute, Indiana)
3.2.1 Chemical Composition of NPL. When tested as in 4.3.1, the result shall match the typical IR curve presented in Fig E16. The presence of additional absorption peaks shall require rejection if the indicative contamination is judged excessive by the analyst.

Note: Rejection criteria are not given

3.2.2 Purity of NPL. The sum of the areas of the gas chromatographic peaks of the impurities, with the exception of the acetone peak, shall not exceed 6% of the area of the peak for NPL, when tested as specified in 4.3.2
3.2.3. Moisture Content of NPL. shall not exceed 0.5%, when tested in accordance with 4.3.3
3.2.4. Ignition or Explosion Temperature of NPL shall be 420 ±30°, when tested in accordance with 4.3.4
3.2.5. Thermal Stability of NPL shall not be lower
than 8 minutes, when tested in accordance with 4.3.5

3.3 Ethylene glycol Dinitrate (EGDN). See the procedure developed at the Trojan-U.S. Powder Company, Allentown, Pennsylvania, 18105, forwarded to us by Mr. W. J. Carroll described here on pp E266-E8

3.3.1. Chemical Composition. The EGDN contg a minimum of 0.25% 2-NDPA shall be tested per 4.3.1. The result shall match the IR Standard presented in Fig. E217. The presence of additional absorption peaks shall require rejection if the contamination is judged excessive by the analyst (See Remark 1 at the end of this item)

3.3.2. Purity of EGDN. The area under the gas chromatographic peak for acetone shall be less than 0.6% of the area for EGDN. The sum of the areas of all other impurity gas chromatographic peaks shall not exceed 0.05% of the area of the peak of EGDN. Test as specified in 4.3.2

3.3.3. Moisture Content of EGDN shall not exceed 0.25%. Test as specified in 4.3.3

3.3.4. Ignition or Explosion Temperature. The EGDN when tested as in 4.3.4, shall ignite or explode at 217 ± 2°

3.3.5 Thermal Stability. When the EGDN is tested as specified in 4.3.5, the result shall be not lower than 8 minutes

3.4. The 2-Nitrodiphenylamine used in the Liquid Propellant shall meet the requirements of Specification MIL-N-3399B, which is included in Vol 5 of Encycl, p D1428-L, under DIPHENYLAMINE AND DERIVATIVES

Note: Acq'd to N.M. Liszt, the bromination procedure should be 10 minutes, instead of 1 minute

3.5 Finished Propellant

3.5.1. Propellant Formulation is given at the beginning of "Ethylene glycol Dinitrate Liquid Propell
for Use in the ADAM Munition". The mixture shall be analyzed by the procedure outlined in 4.3.2. The ratio of the area under the gas chromatographic peak for EGDN shall equal 1.32 ± 0.12. The 2-NDPA shall be analyzed by the procedure outlined in 4.36

4.0 Quality Assurance Provisions
4.1.1. Contractor Quality Assurance System
4.1.2. Submission of Product
4.1.3. Government Verification
4.1.3.1. Surveillance
4.1.3.2. Product Inspection
4.2. Inspection Provision
4.2.1. Lot Formation
4.2.2. Examination

Paragraphs 4.0 thru 4.2.2 above not included in our description of Proposed Specification

4.3. TEST METHODS AND PROCEDURES
4.3.1. Chemical Analysis by Infrared (IR) Method
Chemical identity of the EGDN and NPL used in this propellant and presence of substantial amount of other substances shall be checked by making an IR analysis, using a thin film of sample between KBr windows and comparing these analyses with the appropriate IR absorption curves shown in Figs Et16 & Et17. A typical IR spectrum of finished propellant is shown in Fig Et18

4.3.2. Purity of EGDN, NPL, and the Ratio of Mixtures of these Two Components is suggested to be tested by Gas Chromatographic Analysis, such as described in Vol 3 of Encycl, pp C293-R & C294-L, under CHROMATOGRAPHY

The following conditions shall be used for this analysis:

Column: 5% carbowax 20M on chromasorb 6 (6ft x 1/8-in) column

Carrier gas: Helium at 30 milliliters per minute
Injection port: 150°C
Detector: Flame ionization
Detector oven: 300°C
Oven Temperature: 130°C isothermal
Time per run: 30 minutes

An electronic integrator is used to measure areas and retention times. Using a 1 microliter syringe, introduce a 0.5 microliter sample and start the integrator. Under these conditions, acetone will elute at 0.5 to 0.6 minutes. NPL will elute at 18 to 19 mins and EGDN will elute 1 to 2 mins after the NPL.

Note: N.M. Liszt suggested the use of Fe⁴⁺ for determination of purity of EGDN, but he did not describe the procedure.

4.3.3 Moisture Content Determination by Karl Fisher (KF) Method.

Weigh accurately a 5 to 10g portion of the sample (sample size shall be in accordance with the strength of KF reagent) into a tared narrow-necked flask provided with a stopper. Titrake directly with standardized KF reagent until a brown tinge persists in the soln for 30 seconds.

Note: Potentiometric end point indicators may also be used in titrations.

Calculate as follows:

\[
\text{% Moisture} = \frac{100 \times (VF)}{W}
\]

where: V = Volume in milliliters of KF reagent used in titration
F = Reagent Factor (grams of water per ml of reagent)
W = Weight of liquid proplnt in grams

Note: Detailed description of Karl Fisher Method is given in Vol 5, pp D1622 to D1628-L.

4.3.4. Ignition or Explosion Temperature Determination. It shall be detd using differential scanning
calorimetry. The Perkin-Elmer Model DSC-1B Calorimeter with a number 219-0062 volatile sample sealer accessory may be used in conjunction with a Perkin-Elmer Number 196 Recorder.

Procedure: Place ca 0.25mg of the liq proplnt in a volatile sample pan and seal the pan on volatile sample sealer accessory. Place sample and reference pans in their respective sample holders on the differential scanning calorimeter. Select program heating rate of 20°C per min, range 8 calories per sec, and recorder chart speed of 40mm per min. Start test at RT and program to 250°C. Ignition temp is interpreted to be the point at which the exothermic degradation begins, point A of Fig Et 19. Peak degradation temp is indicated by point B.

Note: Description of "Calorimeter, Calorimetry & Calorimetric Determinations" is given in Vol 2 of Encycl, pp C10 to C12.

4.3.5. Thermal Stability Determination

Procedure: Filter a portion of liq sample thru two thicknesses of "S and S" No 604 filter paper (or equivalent) and transfer (by means of a pipet) a 2ml portion of the filtered material to each of three test tubes, which are 5.5 inches long, 0.5 in internal diam and 0.62 in outside diam. (Care should be taken during the transfer not to leave droplets of the liq on the sides of the test tubes). Stopper each tube by means of a new, tightly fitting cork thru which passes a tightly fitting glass rod equipped with a Pt wire to hold a strip of std KI-starch indicator test paper, ca 1 in long and 3/8 in wide. Moisten a horizontal section in the upper half of the test paper with 50% (by vol) of pure glycerin in distd w. This can be done by dipping
a small diam glass rod into the glyc-

w soln, and as the rod is withdrawn, contact is made with the side of the container so as to reduce the amt of soln adhering to the rod. Then draw the lower part of the rod across the upper strip so as to produce a level and distinct line of demarcation on the lower edge of the wet area. Prepare at the same time a blank by suspending a moistened strip of the same test paper in the clean dry test tube of the same size as tubes with samples. Adjust the temp of the heat tube bath to 82.2 ± 1°C and insert all four tubes simultaneously into the heating soln to a depth of ca 2 inches. Note the time of insertion of the tubes and place the bath in such a position that the test tubes are viewed against a white background illuminated by bright diffused daylight. During the test, the line of demarcation of the papers in all tubes should be 3 inches above the level of liquids in test tubes. Consider the end point of the test to be the first appearance of any discoloration at the line of demarcation betw the wet and the dry portion of the paper in the sample tube which is in excess of the discoloration observed on the test paper of the blank. Note the time of completion of the test to the nearest minute. Consider the lowest time for the three tubes to represent the heat test value of the sample. As was mentioned above the time must be not less than 8 minutes for NPL or EGDN.

Note: After completion of the test empty the tubes and rinse them, as well as rods and corks, with acetone, followed by warm soapy tap w and dried w. Dry in a steam oven at ca 80°.

4.3.6 Determination of Concentration of 2-Nitro-
diphenylamine (2-NDPA) in ECDN and in Liquid Propellant

Weigh 2.000mg of Spec grade 2-NDPA to the nearest 0.02mg on a semimicro analytical balance and transfer to a 100ml volumetric flask. Add 4 drops of concd HNO₃ to dissolve the sample, dilute to volume with concd H₂SO₄ and mix well. Prepare standards by transferring 5.0, 2.0 and 1.0 microliter portions of this soln using a 10 micro-
liter syringe to a 10ml volumetric flask. Dilute to volume with concd H₂SO₄ and mix well.

Transfer 5.0 microliter of the sample (ECDN or liquid propellant), using a 10 microliter syringe to a 10 ml volumetric flask, dilute to volume with concd H₂SO₄ and mix.

Measure the absorbance of the above standards and of the sample using 1.00 centimeter cells, simultaneously with absorbance of concd H₂SO₄ serving as a blank at 540 millimicrons (nanometers). Use a suitable spectrophotometer, such as Beckman Model DU

Calculate the absorptivity from each of the standard solns, using the following equation and average the results

A = k/C

where:

A = Absorptivity; A = Absorbance (measured optical density) and C = concentration in micrograms per 10ml soln. In the above standards, 1 microliter of stock soln contains 0.002 micro-
gram of 2-NDPA.

Calculate the concn of 2-NDPA in the sample using the following equation

%2-NDPA = 20 A/a

where:

A = Absorbance = log₁₀1/T (T is Trans-
mittance - ratio of radiant power transmitted by sample to radiant power incident to it) and a = Mean Absorptivity of above compound

Remark: Mr. N.M. Liszt suggests the use of larger weights in dem of 2-NDPA and trying to find less reactive and dangerous solvents than concd HNO₃ and H₂SO₄. He does not know where the above procedure for 2-NDPA was developed, but both the concn and the wavelength differ greatly from standard method described in MIL-STD-286 for spectro-
photometric determination.

Note: Our rewrite of proposed specification was reviewed by Mr. Nathan M. Liszt, Chief, Analytical Branch, Propellants Div, FRL of Picatinny Arsenal

Ethylenglycol Dinitrate—Nitroisobutylglycol Dinitrate Mixture. A soln of 10 parts NGc serving as an antifreeze in 90 parts of Nitroisobutylglycol Dinitrate (2-Methyl-2-nitro-
1, 3-propanediol Dinitrate) CH₄C(NO₃)₂ (CH₄ONO₂)₂, was prep'd and examined during WWII by the Hercules Powder Co, Wilmington, Delaware. It was found to be a powerful expl with the following properties: Density 1.48 at 28°C and Detonation Velocity (when measured in a glass tube 1 cm ID and 1 mm wall thickness)- 2050 m/sec & 7320 m/sec. It was suggested as a substitute for NG

Ref: G.D. Clift, formerly of Hercules Powder Co (1950) private communication

Ethylenglycol Dinitrate Polymers, O₂NO₃. (CH₃CH₂OHCH₂CH₂)ₙ ONO₃. Two polymers were prep'd by Oehme while nitrating
Ethylene oxide (qv) in presence of sulfuric acid: a) An oily substance contg 12% nitro- 
mine N and (b) A solid contg 9.3% of nitro- 

er. Both were exps of low pow- 
. (See also Ethyleneglycol (Polymers) or 
Polyglycols) 
Ref/s: 1) Beil 1, [521] 2) H.Oehme & Chem 
Fabrik Kalk GmbH, GerP 376000 (1920) 
3) Blatt OSRD 1944 (1944) 4) Curme & John- 
ston (1952) not found

Ethyleneglycol Diphenylether
Ethyleneglycol-di-trinitrobutyrate
Ethyleneglycol Ethylether
Ethyleneglycolglycolate Dinitrate
Ethyleneglycol Lactate
Ethyleneglycol Lactate Dinitrate
Ethyleneglycol Methylether
Ethyleneglycol Methylether Acetate
Ethyleneglycol Monoalkyl Ethers
Ethyleneglycol Monoesters
Ethyleneglycol Monolactate
Ethyleneglycol Monolasocate Acetate
Ethyleneglycol Monomethyl Ether
Ethyleneglycol Mononitrate
See all of above items under ETHYLEN- 
EGYCOL NITRITES AND NITRATES

Ethyleneglycol Monophenylether. See Ethyl- 
englycol Phenylether

Ethyleneglycolonitrile Nitrato. See Glyco- 
nitrile Nitrato

Ethyleneglycol Phenylether and Derivatives
Ethyleneglycol Monophenylether, Phenyl "Cellosolve" or β-Phenoxyethanol;
C₆H₄O.CH₂CH₂OH; mw 138.17 col liq with 
faint aromatic odor; sp gr 1.094 at 20-20°,
µ 134°, fr p 14° bp 240-248°, fl p
240°F, vapor pressure 0.03mm at 20°; sl sol 
in w, sol in alc & eth. Can be prepd by 
heating phenol & ethylene oxide in a closed 
tube at 150°. Used as a solvent for cellulose 
acetate, resins, dyes and inks. Its toxicity 
is reported in Ref 3, p 306 and in Ref 5. On 
its nitration were obt the exps Ethylene-
glycol Dinitrophephyl ether Nitrato (qv) and 
Ethyleneglycol Triinitrophyl ether Nitrato 
(qv)

**Note:** Phenyl “Cellosolve” is Trademark of 
Union Carhise Corp 
Refs: 1) Beil 6, 146, (84) & [150] 2) 
E.Roithner, Monats (1952), 116 & 306 4) 
CondChemDict (1961), 469-L 5) Sax (1968), 
p 748

Ethyleneglycol-2,4-dinitrophenylether Nitrate,
(O₂NO)C₂H₂CH₂O.C₂H₆(NO₂)₂; mw 273.17, 
N15.39%, OB to CO₂ - 67.4%; crys, mp 
64-67°, heat of combst at Cᵥ 3455 cal/g, 
heat of formation 181 cal/g. Can be prepd 
by nitrating ethyleneglycol monophenylether. 
It is an expl sl less powerful than TNT and 
very insensitive to impact. It was proposed in 
Germany for use in smokeless propants & 
detonators
Refs: 1) Beil, not found 2) Westfälisch-An- 
haltische Sprengstoff AG, ChemFabrik, Ger 
PS 48426 & CA 26, 3670 (1932) 3) Ibid, Ger 
P 561306 & CA 26, 4474 (1932) 4) Schmid, 
SS 29, 265 (1934) 5) Curme & Johnston 
(1952) not found

Ethyleneglycol-2,4,6-trinitrophenylether Ni- 
trate, called Nitrade de 2,4,6-Trinitrophenyl-
glycol in Ref 4) 
(O₂NO)C₂H₂CH₂O.C₂H₆(NO₂)₆; mw 318.16, 
N 17.61%, OB to CO₂, -45.3°. Crysts mp 
103.3° (Ref 4); heat of combst at Cᵥ 291.8kcal/mol; 
heat of formation at Cᵥ 66.7kcal/mol. It 
can be prepd by nitrating of Ethylenegly- 
col Dinitrophephyl ether Nitrato or of 
Ethyleneglycol Monophenylether

It is an expl more powerful than TNT. 
It was proposed in Germany for use in deton- 
ators and in smokeless propants 
Refs: 1) Beil, not found 2) Westfälisch-
Anhaltische Sprengstoff AG, ChemFabrik, Ger 
P 548426 & CA 26, 3670 (1932) 3) 
Ibid, Ger P 561306 & CA 26, 4474 (1932) 
4) L. Méard & M. Thomas, MP 39, 345-46 & 
354 (1951)

Ethyleneglycol Polymers Nitratad. Propellants 
contg nitratd polyglycols are descrd in 
Ref. Trancrant prep slabs of 60/40 CP₂ SD
Ethylene glycol nitrates were emulsified in water before incorporation with the NC. A clear decrease in gelatinization power of the nitrates was observed with an increase in the chain length of the glycol.

Ref: J. Tranchant, MP 32, 287-89 (1950)

Ethylene glycol urethanes. See under Glycol urethanes.

Ethylene guanidine and Derivatives

N₂,N'-Ethylene guanidine, Imidazolidone-2-imide, C-NH₂-NHCH₂CH₂NH₂; or Imidazoline-2-amine, C(NH₂)₂-NHCH₂CH₂NH₂; mw 85.11, N 49.37%. The compound has only been prepared in manners which involve salt formation; attempts to isolate it resulted in formation of ammonia and ethyleneurea.

First prep (Ref 2) by heating at 100°C in a closed tube. ICN and ethylene diamine in alc. More recently ethylene diamine has been heated with a salt of 2-C₃H₄-2-thiopseudourea in water at 55°C (Ref 5). Among the known acid salts are the nitric, prisms, mp 115°C sol in w & alc, & the picric, mp 217°C.

Also known are a mono- and a di-silver salt, neither especially stable.


Note: The following derivatives of ethylene guanidine apparently are capable of being isolated in the isomeric forms indicated, plus A(i) mino- or nitra (i) minoethyl guanidines (non-cyclic) & not indicated, depending upon pH, thermal and temporal history of their method of prep.

2-Nitriminoethyleneguanidine or 2-Nitriminimidazolidine,

C(N₂O)₂-NHCH₂CH₂NH₂; mw 130.11, N 43.06%, mp 220-1°C (dec), dip nom 6.93D, sol in water. Prepared by treating nitroguanidine with ethylenediamine dihydrochloride in w at 65-70°C in the presence of KOH.

(Ref 2,4). More recently, ethylene diamine was reacted with 2-methyl-1-nitro-2-thiopseudourea (also a prep for ethyleneguanidine without the nitro) (Ref 8). Treatment with sulfuric or perchloric acids converts this compound to the nitric acid salt of 2-aminoimidazolone, mp 112-13°C (Ref 7).

dine which was heated in water to close the ring. In the same paper McKay reports the $\text{HNO}_3$ salt, mp 161°(dec) prepd by treating the HCl salt with AgNO$_3$, by heating with AgNO$_3$ the acyclic intermediate to the HCl salt, or by nitratting hydroxethyl-nitroguanidine to nitroethylnitroguanidine and heating to close the ring. Most recently cyanogenbromide was reacted with

$$\text{CH}_2\text{CH}_2\text{NC} \rightleftharpoons \text{NH}_2$$

$$\text{N}_2\text{NO}_2$$

to give the HBr salt (Ref 4)


1-Nitro-2-Aminimidazolone-2,
$$\text{C(=NH}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 130.11, N 43.06%. See preceding entry and its Refs and note at beginning of this series of compounds

1-Nitro-2-Nitriminothiophenol or 1-Nitro-2-Nitriminothiophenone,
$$\text{C(=N}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 175.10, N 40.00%, OB to CO$_2$=41.1%, mp 151-2(300C). Prepd by nitratting in sulfure or acetic acetic anhydride of the 2-nitriminothiophenone compd (see above)(Ref 2). Kumler (Ref4) states that the dipole mon of 7.67D and the pK of 6.3 indicate this to be the structure "normally" rather than that in the following entry. Treatment with ammonia followed by HCl open up the ring giving chloroethyl-nitroguanidine (Ref 6). Treatment with AgNO$_3$ in aq alc give a silver salt, which expl over an open flame (Ref 7)


1-Nitro-2-Nitrosoimidazolone-2,
$$\text{C(=NO}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 175.10, N 44.00%. See preceding entry and its Refs and Note at beginning of this series of compounds

1-Nitro-2-Amino-2-Nitriminothiophenone,
$$\text{C(=NH}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 192.13, N 43.74%, OB to CO$_2$=50.0%, crystallizes (from water) mp 184.8 - 5.3(300C). Prepd by adding amonia to the 1-nitro-2-nitrimino in a non-aq system; if water is present, the compd does not form or converts to nitriminoethylnitroguanidine


1-Nitroso-2-Nitrosoimidazolone or 1-Nitroso-2-Nitrosothiophenone,
$$\text{C(=N}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 159.10, N 44.02%, OB to CO$_2$=55.3%, mp 141-2°. Prepd by nitratting the 2-nitrimino compd with nitrous acid (Ref 2). Treatment with aq methylamine at 5-7° displaces the -NO to an an =H (Ref 4)


1-Nitroso-2-Nitriminoimidazolone-2
$$\text{C(=NO}_2\text{)} \rightleftharpoons \text{NCH}_2\text{CH}_2\text{N(NO}_2\text{)}_2$$; mw 159.10, N 44.02%. See preceding entry and its Refs and note at beginning of this series of compounds

Ethyleneimine and Derivatives
Ethyleneimine or Aziridine, $\text{CH}_2\text{CH}_2\text{NH}$
mw 43.07, N 32.52%, frp-74°, Bp 55-6°, sp gr 0.8321 at 24°, nD$^1$ 1.4123 at 25°, sol in w, & organic solvs. Prepd by treating 2-bromoethylamine hydrobromide with silver oxide (Ref 2). Originally thought to be vinylamine, and not correctly identified until 11 years later (Ref 3).

In 1963 Dow Chemical introduced the method.

E 281
of prepn by heating ethylene dichloride with ammonia (in excess or with CaO) at 100°.
Most salts are unstable at room temperature, giving ring opening, but the picrole is stable.
mp 142°; yel. Ethyleneimine is extremely toxic and corrosive to all tissue (Ref 6)
Refs: 1) Beil 20, 1, (3) & (3) 2) S. Gabriel,
Ber 21, 1049(1888) 3) C. C. Howard &
& W. Marchwald, Ber 32, 2036(1899) 4) A. Weissberger, ed, "Chemistry of Hetero-
cyclic Compounds", Interscience-Wiley,
NY 19, (1964), p 524-L (P. Fanta) 5) "Ethyl-
eneimine", The Dow Chemical Co, Midland,
(0.C. Dermer & A. W. Hart, 163 refs) 7)
Sax (1968), 748

N-Nitrosoethylamine or N-Nitrosouaziridine,
CH2=CHNO2; MW 72.07, N 38.86%. Prepd
by adding N/OCl dropwise to ethyleneimine, add
tritylamine in eth at 70°. The resulting
yl soln is stable at 60°, but decolorizes on
warming. Above 0° decomp to ethylene and
nitrous oxide occurs.
Refs: 1) Beil, not found 2) W. Rundel &
E. Mueller, Ber 96, (9), 2528-31(1963) & CA 59,
12626(1963)

Note: No other derivatives of ethyleneimine of
the type NO2 or N2 were found in Beil or through
CA 75

Ethylene Nitrate See under Ethylene Glycol
Dinitrate in this volume

Ethylene Nitrate See under Ethylene Glycol
Dinitrate in this volume

Ethylene Nitro, O2NCH=CHNO2; MW 118.05,
N23.73%, OB to CO2, 13.5%, mp 64°. Prepd
by treating an ether suspension of the dissodium
salt of 1,2-dinitroethane at -50° with bromine.
It is not stated in any of the refs whether it is
the cis or trans isomer.
Refs: 1) Beil, not found 2) E. S. Lipina, et al.,
Zh Org Khim 5(7), 1312-13 (1969) & CA 71,
& CA 72, 120999 (1970) 4) Ibid, Dokl Akad-
CA 73, 55570 (1970)

Ethylene Nitrosite. See Ethylene Nitrosite
in this Vol

Ethyleneoxide and Dinithylothlenoxamidne.
They are described in Vol. 5 of Encycl, pp
D1299-R & D1300-L, under Diketopiperazine
and Derivatives.

A different method for prepg ethyleneox-
amide than that given on p D1299-R was de-
scribed by J. van Alphen, Rec 54, 937 (1935),
who also described on p 938 prepn of N,N-
Dinithylothlenoxamidne listed on p D1299-R
of Encycl as 1,4-Dinitrodiketopiperazine.

Another method of prepn of Dinithylothlen
oxamide was described by W. E. Bachmann,
JACS 72, 3133 (1950). He prepd it by stirring
gradually 15 g of ethyleneoxamide into a
freshly prepd mixture of 40 g, 98%, white nitric
acid and 40 g acetic anhydride, kept at 5°C
or below. Then the nitrated mix was placed
in a refrigerator and kept there for 20 hours.
The resulting ppt was collected on a sintered
glass filter and rinsed with acetic acid.

After drying, 16.6 g of product melting at 180-
185° was collected.
Bachmann also obtd 5.2 g of EDNA by warming
for a few minutes on a water bath. 8 g of Di-
nithylothlenoxamidne in 10 ml of 28% of
ammonia.

ETHYLENE OXIDE (EtO) Epoxethane or
Dimethylene Oxide, H2C=CH2; MW 46.06; O
pleasant smelling, flammable liquid, sp gr
0.8697 at 20°; fr p -111.3°, bp 13.5° at 747mm;
N2, 364 at 6.4% or 1.3597 at 7°, flash p (tag
glass open cup) < 0°F; coeff of expansion
0.0017 at 55° dielectric constant 13.9 esu
at -1°C; ignition temp in air at 760mm 429°C
(Parkin); spontaneous ignition temp (SIT)
804°F (429°C); (IEC 32, 882(1940)); vapor
pressure at 20°F 1095mm; viscosity (absol) at
0° 0.32cp; surface tension 24.3 dynes at
20°; heat of combustion at 25° & 760mm
312.5±0.20 kcal/mol; heat of formation-vapor
17kcal/mol & liquid 23.3kcal/mol; heat of
fusion 1236.4kcal/mol; heat of vaporization at
760mm and 10.5°C 6082cal/mol- thermal conductivity of vapor at 25°C 0.00002961 cal·cm/sec·cm²/°C. It does not corrode metals

EmO is very sol in w, alc, ether, dichloroethane and other org solvents. Although aqueous solns of EmO conduct electricity, the compd itself is not conductive; when, however, a salt like NaCl or KNO₃ is dissolved in EmO, the resulting soln is conductive

Physical properties of EmO are listed on pp 87-94 of Curme & Johnston's book (Ref 17), while its chemical reactions are described on pp 94-106

Wurtz (Refs 1 & 2) was the first to prep it in 1859, thus laying the foundation for the "chlorohydrin process" curntly used in industry. A procedure by which oxygen can be added directly to the ethylene bond was discovered in 1931 by Lefort and patented in 1935 (Ref 6a). His research led to the development of a second major process for EmO manuf, known now as "direct oxidation" (Ref 17, p74)

The Carbide and Carbon Co began large scale manuf of EmO thru ethylene chlorohydrin in 1925 and by the direct oxidation of ethylene in 1937. Dow entered the field in 1939 & 1941; Jefferson and Wyandotte in 1941 and Mathieson Chem Corp in 1951. These four Co's used the chlorohydrin method. US consumption, which was in 1939 108 million pounds, increased in 1949 to 354 million

Several laboratory methods of prep are described in Ref 17, pp 75-7. In one of them hydroxide is added gradually to a soln of 2-chloroethyl acetate heated to a temp betw 40 & 150°C. An excess of unreacted base is avoided. The reaction proceeds as follows:

\[
\begin{align*}
\text{CH}_2\text{Cl}_2 + 2\text{KOH} & \rightarrow \text{CH}_3\text{O} + \text{KCl} + \text{CH}_2\text{COOK} + \text{H}_2\text{O} \\
\text{CH}_2\text{O} - \text{C} - \text{CH}_3 & \rightarrow \text{CH}_3
\end{align*}
\]

Commercial prep of EmO by chlorohydrin method is based on the following reaction:

\[
\begin{align*}
\text{CH}_2\text{HOCI} + \text{CH}_2\text{OH} + \text{NaOH} & \rightarrow \text{CH}_2\text{OH} + \text{NaCl} + \text{H}_2\text{O} \\
\text{CH}_2\text{O} & \rightarrow \text{CH}_3\text{Cl} + \text{CH}_3
\end{align*}
\]

This method is described in Ref 17, pp 16-19 & 77 and in Ref 13

\[
\text{CaOH}_2 \text{can be used instead of NaOH, as described by Messing (Ref 13a)}
\]

The direct catalytic, oxidation method of ethylene is described in Ref 17, pp 77-87: Explosibility. Liquid ethylene oxide is stable to detonating agents, but the vapor will undergo explosive decomposition. Pure ethylene oxide vapor will decompose partially; however, a slight dilution with air or a small increase in initial pressure provides an ideal condition for complete decomposition. Copper or other acetylide-forming metals such as silver, magnesium, and alloys of such metals should not be used to handle or store ethylene oxide because of the danger of the possible presence of acetylene. Acetylides detonate readily and will initiate explosive decomposition of ethylene oxide vapor. In the presence of certain catalysts, liquid ethylene oxide forms a poly-condensate.

This reaction is highly exothermic. If the heat of the reaction is not conducted thru the walls of a closed container at a rate capable of maintaining an equilibrium temperature, an increase in pressure results with an increase in reaction rate, leading to explosive conditions. Acid salts, such as stannic chloride and zinc chloride, and bases, such as alkali metal hydroxides, either solid or in aqueous solution, and tertiary amines are all effective catalysts. It is, therefore, imperative that the concentration of such contaminants be kept at a minimum when transporting or storing sizeable quantities of ethylene oxide.

Accdg to Hess & Tilson (Ref 16), a 90% decomp takes place if 100% vapor of EmO in a closed container is initiated with MF. There is no upper limit of EmO in air (the previously reported value of 80% was in error), but the lower expl limit is 3% (Ref 17, p 87)

Toxicity of EmO (Ref 17, pp 314-15 & Spec MIL-E-52171). Liquid EmO, concentrated or dilute, when exposed to the skin can cause severe delayed burns. Short exposures produce mild first degree burns, but protracted exposures produce second degree burns with the formation of large blisters. Exposure to the vapor results in systemic manifestations and irritation to the respiratory system. Inhalation of ethylene oxide vapors, if prolonged, results in severe systemic poisoning with the symptoms of nausea, vomiting, headache, dysnea, and diarrhea. The anesthetic properties are similar to chloroform, but with pronounced undesirable side and after effects.
Tests on guinea pigs have shown that a 5 percent by volume concentration of ethylene oxide vapor kills in a short time. The maximum concentration for 60 minutes without serious disturbance was 0.3 percent by volume. The odor of EtO is inadequate to serve as a warning of dangerous concns. Some authorities consider that concns as low as 250ppm have some effects on humans and that 500ppm is dangerous. Concns used for fumigation are not highly toxic, but they can cause cyanosis. Skin exposure to liquid EtO can cause severe delayed burns.

Uses of EtO: It has been used chiefly as an intermediate for prepns of other compds, such as of ethyleneglycol, other glycols, alcohols, etc. (Ref 13, 17 & 18). Its hydration to ethyleneglycol is described in Ref 17, p 20.

EtO has also been used as a disinfectant or fumigant (Ref 17, p 108 & Ref 18). Technical EtO mixed with some carbon dioxide or chlorofluor hydrocarbons (to remove the explain hazard) is intended for use as a biological decontaminant (See Ref 19). Nearly pure (99.9%) EtO is used as a liquid propellant (Ref 21). Its use as a monopropellant is discussed in Addnl Refs 1 & J Analysis of EtO and its homologues:

According to Curme & Johnston (Ref 17, p97), with certain metallic halides in neutral aqueous soln, EtO reacts with the acid freed by dissociation and hydrolysis to ppt the metallic hydroxide. This reaction serves as a basis of analysis for EtO and its homologues. It proceeds as follows:

\[ \text{MgCl}_2 + 2\text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + 2\text{HCl} \]

The halides of aluminum, iron, tin, zinc and manganese react in similar manner with EtO in neutral aqueous soln.

Deckert (Ref 6, quoted from Ref 17) developed a qualitative test for EtO based on the reaction with aqueous NaCl which results in the formation of ethylene chlorohydrin and NaOH.

Lubatti (Ref 8, quoted from Ref 17) developed a quantitative test for EtO using HCl in a saturated soln of MgCl2.

The nitration of EtO in the presence of sulfuric acid yields Ethyleneglycol Dinitrate:

\[ \text{H}_2\text{C}=\text{O} + 2\text{HNO}_3 \rightarrow \text{CH}_2\text{ONO}_2 \]

Ref 17, p 104 & Addnl Ref F

Refs for EtO:

Addnl Refs for EtO:
C) Koch, Arbeitschutz 1943, 317 & CA 40, 6259 (1946) (Serious expln caused by EtNO is discussed) D) A.K. Gupta, JSCI 68, 179–83 (1949) & CA 43, 8138 (1949) (EmO in the presence of small amounts of acids, bases, or some salts might undergo a spontaneous polycodensation of explosive violence) E) Anon, Chem&Engrs News 27 (35), 2500 (1949) (Brief description of explns reported by Gupta and recommendations for prevention of such explns)

**Ethylene Oxide, Technical**

Military specification MIL-E-52171, 27 April 1961 and Amendment 1, 6 October 1961. Material described in this test is used with added carbon dioxide or chlorofluorohydrocarbons (to prevent expln hazard) as a biological decontaminant.

**Requirements:**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Assay [(CH₂)₂O]</td>
<td>99.0 min</td>
</tr>
<tr>
<td>2) Water</td>
<td>0.030 max</td>
</tr>
<tr>
<td>3) Acidity (as acetic acid)</td>
<td>0.002 max</td>
</tr>
<tr>
<td>4) Aldehydes (as acetaldehyde)</td>
<td>0.010 max</td>
</tr>
<tr>
<td>5) Chlorides (inorganic)</td>
<td>none</td>
</tr>
<tr>
<td>6) Acetylene</td>
<td>none</td>
</tr>
<tr>
<td>7) Nonvolatile residue</td>
<td>0.010 g max</td>
</tr>
<tr>
<td></td>
<td>(per 100 ml)</td>
</tr>
<tr>
<td>8) Color</td>
<td>15 max on the Pt-Co scale</td>
</tr>
</tbody>
</table>

**Tests:** Tests shall be conducted as follows:

Exercise care in the handling of ethylene oxide as it is an explosive and toxic material. Conduct all tests in a ventilated hood. Use analytical grade reagents and distilled water throughout the tests. Run blank determinations in parallel with the tests, using the same quantities of reagents, and apply corrections when significant. Determine the specific gravity of the specimen at 1°C±1°C by means of a suitable hydrometer, and use the figure obtained for calculations.

**Preparation of specimen.** Suspend a small bottle and metal carrier similar to Fig Et 20 in a dry ice-acetone bath contained in a Dewar flask. Fill the bottle to the shoulder with a portion of the sample ethylene oxide and cover the bottle with a glass plate. Dry a borosilicate glass bulb 18 to 22 mm in diameter having a narrow stem approx 50 mm long in an oven at 105°C±5°C, cool it in a desiccator, and weigh it to the nearest 0.1 mg.

Place the bulb in the glass dipper, and replace the glass plate with the bulb and dipper as shown on Fig Et 20. Cover the bulb in the glass dipper with carbon dioxide snow, and allow sufficient time to elapse for 1 g of the sample to be drawn into the bulb. Immediately remove the glass dipper by the handle, invert the bulb, and then hold the bulb stem at an angle of approximately 45° from the vertical. Bring the stem near a gas flame to warm slightly. When the liquid leaves the capillary, seal the bulb quickly with the gas flame while the bulb is still in the carbon dioxide snow.

**Procedure.** Remove the bulb from the glass dipper. Allow the bulb to come to room temperature in a desiccator and weigh to the nearest 0.1 mg. Place 150 g of magnesium chloride, 125 ml of saturated magnesium chloride solution, and 30 ml of 1N sulfuric acid in a 500-ml heavy-wall, glass-stoppered Erlenmeyer flask. Thirty milliequivalents of sulfuric acid are approximately equal to 1.34 g of 99.0% ethylene oxide. If the normality of the sulfuric acid is much less than 1N, an additional quantity of acid should be added to make a total of 30 milliequivalents. Also, if the sample is 1.34 g or more, additional acid and magnesium chloride should be added.

Introduce the sealed sample of ethylene oxide into the Erlenmeyer flask and stopper tightly, taking care not to break the bulb. (Since the flask must be sealed, the stopper should be reground with No 300 carborundum and greased.) Cool in an ice bath to 1°C±1°C. Remove the
GLASS DIPPER WITH HANDLE

GROUND SURFACE

METAL CARRIER

2 MM HOLE

FIGURE E120 BOTTLE AND METAL CARRIER
flask, wrap with a towel, and holding the stopper down tightly, shake to break the bulb. Allow the contents to react, shaking intermittently for 15 minutes. If the bulb is not completely shattered by shaking, crush the stem with a stirring rod. Titrate the excess acid with 0.1N sodium hydroxide to a bromocresol purple endpoint (yellow to blue). Run a blank titration on the reagents, using exactly the same amount of sulfuric acid. Calculate as follows:

\[
\% \text{ EmO} = \frac{(B-A)N \times 4.405}{g \text{ of sample}}
\]

where: \( A \) = ml of NaOH soln required for the sample, \( B \) = ml NaOH soln required for the blank, \( N \) = normality of the NaOH soln

Retest. Retest the lot if the results of tests of the composite and the individual samples vary over a range greater than 0.3%. Water. Determine the water content of a 50-ml specimen of the EmO as specified in ASTM Standard D1364. Calculate the weight of the specimen tested using the specific gravity of the ethylene oxide determined by means of a suitable hydrometer.

Acidity (as acetic acid). Using a chilled 100-ml graduate, measure a 68-ml (60g) portion of the sample into a 250-ml Erlenmeyer flask. Allow the portion to evaporate to about 50ml to release any carbon dioxide in the sample. Immediately add 3 drops of a 1.0% soln of phenolphthalein in a 1:1 mixture of methanol and water, and titrate with an aqueous 0.01N NaOH to a pink end point which persists for 15 secs. Calculate the acidity as acetic acid using the formula:

\[
\% \text{ Acidity (as acetic acid)} = \frac{A \times N \times 6.0}{B \times G}
\]

where: \( A \) = ml of 0.01N NaOH, \( N \) = normality of NaOH, \( B \) = ml of EtNO, \( G \) = specific gravity of sample

Aldehydes (as acetaldehyde). Reagents: Sodium metabisulfite solution (0.1N). Dissolve 4.75 to 5.00g of sodium metabisulfite in sufficient water to make 1000ml of solution. Adjust the pH of the solution to 3.5 by adding 0.5N sulfuric acid. Make up a fresh solution daily. Do not use this solution after the pH drops below 3.0

Iodine solution (0.1N). Dissolve 13.5g of iodine in 200ml of water containing 24g of KI. Dilute the solution to 1000ml with water. Standardize the soln against standard sodium thiosulfate or standard sodium arsenite solns.

Procedure. Transfer 25.0ml of distilled water to each of four 500-ml glass-stoppered Erlenmeyer flasks and cool them to approx 0°C. Carefully pipet 20.0ml of the 0.1N sodium metabisulfite soln into each flask, using the same pipet for each transfer and holding the tip of the pipet under the surface of the water in the flask during delivery. Cool the contents of the flasks to approx 0°C, and set aside two of the flasks for blank determinations. Using a 50-ml graduate cooled by rinsing with portions of the cooled sample, pour 50ml of the sample into each of the other two flasks. Swirl the contents of the flasks to effect soln. Allow the four flasks to stand, at room temp, for at least 10 mins but not more than 30 mins with occasional swirling. Add 10ml of water previously cooled in an ice bath to each flask. Immediately titrate the contents of each of the flasks with 0.1N iodine solution until the yellow color begins to persist, add 5ml of freshly prepared 1.0% aqueous starch indicator, and continue the titration to the first permanent blue end point. Calculate as follows:

\[
\% \text{ Acetaldehyde} = \frac{(B-A)N \times 2.2}{50 \times G}
\]

where: \( A \) = ml 0.1N iodine soln required for sample, \( B \) = average ml 0.1N iodine soln required for blank, \( N \) = normality of iodine soln, \( G \) = specific gravity of sample

Chlorides (inorganic). Place 40ml of water in a 250-ml glass-stoppered Erlenmeyer flask and cool the water in an ice bath. Add approx 10ml of chilled EmO sample, 10 drops of concd nitric acid, and about 10ml of approx 0.1N silver nitrate soln. Report the presence of inorganic chlorides if a ppt is formed.

Acetylene. Reagents: Mixed indicator. Dissolve 0.10g of methyl red and 0.050g of methylene blue in 100ml of 95% ethyl alcohol conforming to grade 1, class B, of Specification O-E-760. Mix the solution thoroughly and store it in a dark-colored bottle.

Silver nitrate solution. Dissolve 25g of silver nitrate in 150ml of water contained in
1000-ml volumetric flask. Mix the soln thoroughly and dilute to the mark with 95% ethyl alcohol conforming to grade I, class B, of Specification O-E-760. Mix the soln thoroughly.

**Procedure.** Transfer 150.0±ml of the silver nitrate soln to each of two 250-ml glass-stoppered Erlenmeyer flasks. Place the flasks in a suitable ice bath until the temperature of the contents is 2±2°C. Add 7 to 9 drops of the mixed indicator to each of the flasks and, if necessary, neutralize the soln to a gray-green color with 0.02N NaOH, if acid, or with 0.02N nitric acid if alkaline. Remove one of the flasks from the ice bath for the blank. Using a chilled graduate, pour 50±1 ml of the sample into the flask remaining in the ice bath. Swirl the flasks and compare the colors of the contents. Report the presence of acetylene if the soln containing the sample turns to a purple color. (If a positive test is obtb, destroy the silver acetylide by adding an excess of acid ferrous sulfate soln to the contents of the flask before discarding the soln.)

**Non-volatile residue.** Measure approx 100ml of the cold sample into a chilled 100-ml graduate and place it in a tared borosilicate glass evaporating dish. Allow the EtOH to evaporate to dryness at RT. Place the dish in an oven at 105°C to 110°C for 30 mins. Cool the dish in a desiccator and reweigh it to the nearest mg. Calculate the non-volatile residue by subtracting the tare wt from the wt of the dish containing the residue.

**Color.** Standards: Stock standard. Dissolve 1.245g of potassium chloroplatinate (K₃PtCl₆) and 1.000g of cobaltous chloride (CoCl₂·6H₂O) in water. Add 100ml of concd HCl, and dilute the soln to 1000.0ml with water. (This soln has a color of 500 on the APHA and ASTM platinum-cobalt scales)

**Test standard.** Dilute 3.0ml of the stock standard to 100.0ml with water. (This soln represents a color of 15 on the Pt-Co scale)

**Procedure.** Fill one of a pair of matched tall-form 100-ml comparison tubes to the mark with the test standard. Chill the second matched tube and fill it to the mark with the chilled sample. Immediately compare the colors of the test standard and the sample by viewing vertically down thru the tubes using a white background. Report the sample as passing the requirement if the sample is no darker than the test standard.

**Acceptance/rejection criteria.** If either sample fails to meet the requirements of this specification, the lot represented shall be rejected.

**Propellant, Ethylene Oxide**
Military Specification MIL-P-8845A, 30 June 1969, superseding MIL-P-8845(ASG), 20 April 1959

**Requirements:**
1) Assay [(CH₂)₂O] % by Weight 99.9 min
2) Acidity (as acetic acid) 0.005 max
3) Water 0.03 max
4) Iron, ppm/wt 0.1 max
5) Aldehyde (as acetaldehyde) 0.03 max
6) Chloride 0.02 max
7) Non-volatile residue 0.01 max
8) Acetylene non detectable

**Reagents Used in Tests:**
A) **Mixed indicator.** Dissolve 0.10g of methyl red and 0.050g of methylene blue in 100ml of 95% ethanol. Mix and store in a brown bottle.
B) **Silver nitrate solution.** Dissolve 25g of ACS reagent grade silver nitrate in 150ml distilled water contained in a 1000-ml volumetric flask. Mix thoroughly and dilute to the mark with 95% ethanol.
C) **Sodium hydroxide solution, 0.02N.** Dissolve 0.8g of ACS reagent grade NaOH in distilled water in a 1000-ml volumetric flask. Dilute to the mark with distilled water.
D) **Nitric acid solution, 0.02N.** Dilute 1.3ml of ACS reagent grade concd nitric acid to the mark with distilled water in a 100-ml volumetric flask.
E) **Acid ferrous sulfate solution, 0.5N.** Dilute 8g of ACS reagent grade ferrous sulfate heptahydrate (FeSO₄·7H₂O) to the mark in a 1000-ml volumetric flask with distilled water. Add three drops of concd sulfuric acid

**Equipment:**
a) Volumetric flasks, 1000ml and 100ml
b) Graduated cylinder, 250ml
c) Erlenmeyer flasks, 250ml, glass-stoppered
d) Ice bath

**Sampling procedure.** For taking a sample from its shipping container, attach to its valve the valve V₁ of tared sampler shown in Fig E21. With valves V₁ and V₂ closed cool the sampler to 0°C(32°F) with ice. Open the container valve and then valve V₁ of the
The propellant sample size shall be approximately 50 ml. Determine the weight taken by weighing the sampler to the nearest 0.1g before and after the liquid is removed.

Calculate the results as follows:

\[ \text{Acidity as acetic acid, } \% W_t = \frac{\text{ml} \times N \times 0.06005 \times 100}{W} \]

where:

- \( \text{ml} = \) milliliters of NaOH used
- \( N = \) normality of NaOH
- \( W = \) propellant sample weight titrated

3) Water. The water content shall be determined in accordance with ASTM E203-64, with the following exception:

**Exception.** The propellant sample size shall be approximately 50 ml. Determine the weight taken by weighing the sampler to the nearest 0.1g before and after the liquid is removed.

4) Iron. The iron content shall be determined in accordance with D1068-62T, Method A, with the following exceptions:

a) The propellant sample size shall be approximately 100 ml. Determine the weight taken by weighing the sampler to the nearest 0.1g before and after the liquid is removed.

b) Place the propellant sample in an evaporating dish and evaporate to dryness. Add 5 ml of concentrated HCl to the residue and evaporate the mixture to dryness. Swirl the mixture during evaporation to assure quantitative digestion of the residue. Quantitatively transfer the residue to a 100-ml volumetric flask with three 2-ml portions of 0.5N HCl. Proceed with the Method A analysis.

c) An absorption cell with a 10-cm optical path shall be used.

Calculate the results as follows:

\[ \text{Iron, ppm/wt} = \left( \frac{W}{W_a} \right) \times 1000 \]

where:

- \( W = \) milligrams of iron found
- \( W_a = \) propellant sample wt in grams

5) Aldehyde. The aldehyde content of the propellant shall be determined in accordance with ASTM D2191-65 with the following exceptions:

a) The propellant sample size shall be approximately 50 ml. Determine the weight taken
by weighing the sampler to the nearest 0.1 g before and after the liquid is removed.
b) Substitute a 12-oz heavy-wall aerosol compatibility tube with closure for the 500-ml
glass-stoppered Erlenmeyer flask used for the titration.
c) Substitute "W", the propellant sample
weight in grams taken, for "W x M" in the
formula for aldehyde content.

6) Chloride. The chloride content of the
propellant shall be determined in accordance
with ASTM D512-62T, Method A, with the
following exceptions:
a) The propellant sample size shall be approxi-
ately 50 ml. Determine the weight taken
by weighing the sample to the nearest 0.1 g
before and after the liquid is removed.
b) Place the sample in an evaporating dish and
add 5 ml of 0.25N NaOH. Evaporate
the mixture to dryness and with distilled
water quantitatively transfer the residue to
a 250-ml Erlenmeyer flask. Proceed with
the Method A analysis.

7) Nonvolatile residue. The nonvolatile residue of the propellant shall be determined in accordance with ASTM D1353-64 with the following exception:
The propellant sample shall be approximately
100 ml. Determine the weight taken by weighing
the sample to the nearest 0.1 g before
and after the liquid is removed.

8) Acetylene. The acetylene content of the
propellant shall be determined by the follow-
ing procedure:
Transfer 150 ml of the silver nitrate reagent
to each of two 250-ml glass-stoppered Erlen-
meyer flasks. Place the flasks in a suitable
ice bath until the temperature of the contents
is 32° to 39.2°F (0° to 4°C). Add 7 to 9
drops of the mixed indicator to each flask and,
if necessary, neutralize to a gray-green color
with 0.02N sodium hydroxide if acid; or with
0.02N nitric acid if alkaline. Reserve one of
the flasks for the blank and into the second
flask pour 50 ml of propellant. Compare the
color of the sample with that of the blank. A
purple color in the sample solution indicates
the presence of acetylene.

Note: If a positive test is obtained, destroy
the silver acetylide by adding an excess of
acid ferrous sulfate solution to the sample
flask before discarding the solution.

Ethylene Ozonide (Áthelyleneozonid in Ger).
H₂C=O·CH₂; mw 76.06, colorless, unstable,
oily liq with pungent odor, sp gr 1.265 at
17.5/17.5°, N₂O₄ 1.4099 at 17.5°, bp 18° at
16mm; explodes violently on heating or by
friction; decomposes explosively when treated
with strong NaOH soln. Can be prepd by
the action of purified Ozone on a soln of
ethylene in methylchloride at -70° in the
complete absence of water (Refs 1 & 2).
Ozonization of ethylene also was described by
Briner & Schnorf (Ref 3).
Criegee (Ref 4) reported that one of the
laboratory workers prepd and purified about
500 mg of ozonide using the method described
in Refs 1 & 2 and then left the product
standing till next day. On transferring it
into another vessel a violent exphn took
place accompanied by a bright flame.

This ozonide also is described by Tobolsky & Mesrobian (Ref 5)
Refs: 1) Beil 1, 184 & 1633] 2) C. Harries &
R. Koetschau, Ber 42, 3305(1909) 3)
E. Briner & P. Schnorf, Helv 12, 154(1929)
4) R. Criegee, AGnewChem 65, 390(1953) &
CA 47, 11737(1953) 5) Tobolsky & Mes-
robian (1954), 180

Ethylene Pseudonitrilotisite,
O₂N·CH₂·CH₂·NO₂, ON·CH₂·CH₂·NO₂; mw
208.14, N₂6.92%, OB to CO 24.62%; ndls,
mp 116-17°(dec), sol in concd H₂SO₄, insol
in w, sl sol in alc. Prepd by passing ethyl-
ene and N₂O₄ (Ref 2) or N₂O₃ (Ref 4) through
eth. The structure was first hypothesized
in Ref 3, and later assumed in Ref 4, but
there is no confirmatory evidence. Marshall
(Ref 4) proposed its use as a secondary
charge in blasting caps, e.g. a base charge
of 0.4-1.0 g ethylene pseudonitrilotisite over a
priming charge of MF, etc., in a copper shell
Ethylene pseudonitrilotisite is comparable in
power and brisance to Tetryl.
Refs: 1) Beil 1, 184 & (77) 2) N. J. Dem-
Ethylene Tetrafluoride or Tetrafluoroethylene
(Perfluoroethylene), \( F_2C:CF_2 \); m.w. 100.02; col. gas, fr p -142.5\(^\circ\), bp -78.4\(^\circ\); insolv in w. Was prepd by Humiston (Refs 1&2) by treating charcoal with fluorine; carbon tetrafluoride was obtd at the same time. Accdg to Ref 3, it can be prepd by passing chlorodifluoromethane thru a hot tube. Serves as a raw material for prep of polytetrafluoroethylene polymers (Ref 3).

Note: Accdg to Dr J.V.R. Kaufman, formerly of PicArsn, Minnesota Mining and Manufacturing Co. of Minneapolis, Minn experienced in their laboratory an exphn which was probably caused by sudden polymerization of Ethylene Tetrafluoride. This exphn caused the loss of an arm of one of the investigators trying to purify the material by distillation.


Ethylendiepentaamine or Tetranitraminoethyl-
ene, \( (N_2)NHNH2C2H5N(NO2)2 \); m.w. 240.09, N23.34% (NO2), OB to CO2+. 13.3%, liq. Prepd by reacting ethylenediamine dinitra-
mine with nitromine fluoroborate in acetoni-
trile at 30\(^\circ\) (Ref 3). No props are given.

Refs: 1)Beil, not found 2)ADL, Synthesis HE's, 2nd Report (1951), p 220 3)Aero-
jet General Corp, BritP1126591 (1968) & CA 70, 67584 (1969)

Ethylene-iso-thiourea and Derivatives
Ethylene-iso-thiourea, 2-diaminobenzamide
or 2-Amino-2-thiazoline
\( [\text{NH}]\text{NHCH}_2\text{CH}_2\text{Cl} \; \text{or} \; \text{SC(NH}_2\text{)CH}_2\text{Cl}; m.w. 102.16, ndls or flakes (from benz), mp 84.5\(^\circ\), sol in w, alc., chl & warm benz. Prepd from 2-bromoethylamine hydrobromide and potassium rhodanide. There is a picrate, ndls (from w), mp 235\(^\circ\) (dec).

Refs: 1)Beil 24, 2, (184) & (3) 2)E. Fischer & H. Koch, Ann 232, 227 (1886) 3)G.C. Halle, USP2430874 (1947) & CA 43, 691 (1949). Description of prep from ammonium carbonate and an ethylene derivative such as ethylene-
diamine, ethylene oxide or ethyleneglycol)
4) J. F. Mulvaney & R. L. Evans, IEC 40, 393-7
(1948) (15 refs) 5) W. E. Bachmann, et al.,
JACS 72, 3133 (1950) 6) CondChemDict
(1971), 367

N,N'-Dinitroethyleneurea (DNEU); 2,5-
Dinitro-2,5-diazacyclo-1-pentanone or 1,3-
Dinitro-2-imidazolidone

\[
\text{H}_2\text{C} - \text{N} = \text{N}\text{NO}_2
\]

\[
\text{H}_2\text{C} - \text{N} = \text{N}\text{NO}_2
\]

mw 176.09, N15.91% (NO2) OB to CO2
-27.1% wh prisms (from hot alc), density
1.796(cryst), 1.65 (loading), mp 216-217°
decomp), explodes at higher temps, insol
in water and in most org solvents, diff sol
in boiling alc, hydrolyzes to ethylenedinitra-
mine on boiling with water. Was first prep
by Franchimont & Klobbie on treating ethy-
lenearuea with concd nitric acid (Refs 1 & 2).
Aaronsen of PicArsn found that by using
mixed nitric-sulfuric acid instead of straight
nitric acid yields were increased from 53-60%
to 92-95% of theory. In his laboratory pro-
cedure 1 part of powdered ethylenearuea was
slowly sifted with stirring, into 10 parts of
mixed acid (HNO3 22.0, H2SO4 68.5 &
H2O 9.5%) maintained during addition at be-
low 10°. Stirring continued for 1-2 hours
allowing the temp to rise but not above 30°.
Then the slurry was filtered and ppt washed
with water and dried. Methods of nitrations
were examined during WWII by the duPont Co
(Ref 5) and it was concluded that nitratio
with straight strong nitric acid is preferable
to nitratio with mixed acid. Caesar & Gold-
frank (Ref 7) patented a method of prep-
DNEU by nitratio at low temp of ethylenearuea
dissolved in an inert solvent (such as CHCl3)
employing either nitrogen pentoxide or concd
HNO3. Yields of nearly 100% were claimed.

Properties of DNEU (Ref 6 & other sources)
Brisance - nor dned
Detonation Velocity- 7690 m/sec at d 1.60
and 7890 at d 1.65, for unconfined charges
2.5 x 40 cm

Explosion Temperature - 235-240° in 5 seconds
Heat of Combustion - 388 kcal/mol
Heat of Formation - 312 kcal/mol
Hygroscopicity - gained 9.12% at RT &
100%RH in 24 hours
Impact Sensitivity - between those of TNT
and Tetryl

Power by Ballistic Mortar - 129% TNT
Power by Trauzl Test - 120% TNT
Stability - fairly stable at below mp
Thermal Stability at 135° - not acid and no
expln in 300 minutes
Vacuum Stability at 120° - 7.4cc gas
evolved per 5g in 25 hours

Uses: As an intermediate for prep of
EDNA, described in this Vol as Ethy-
lenedinitrime under Ethylenediamine.
It is suitable for use as booster charges
and as base charge in blasting casts and
detonators (Refs 4 & 6)

Refs: 1) Beil 24, 4
2) A.Franchimont
& E.Klobbie, Rec 7,16 & 243 (1888)
3) H.Aaronson,USP 2149260 (1939)
4) W.H. Rinckenbach & H.Aaronson, USP
2167679 (1939) & CA 33,8992 (1939)
5) E.I. du Pont de Nemours, OSRD Rept
3466 (1944) 6) Blatt,OSRD Rept 2014
(1944) 7) G.Caesar & M.Goldfrank,
USP 2400288 (1946) & CA 40,4523 (1946)

Ethylester of Benzoylbenzoic Acid. See
Ethyl-o-benzoylbensolate in this vol

Ethylester of Carbamic Acid or Urethane.
See Carbamic Acid Ethylester in Vol 2 of
Encycl, pp C40-R & C41-L

Ethylester of Dimethylaminocyanophos-
phoric Acid. See GA Chemical Warfare
Agent described in Vol 2, p C167-R.
Originally, it was Geman Agent of WWII
called Tabun, Trilon, T83 or T100,
described in PAK 2510 (1958), pGet
204-L

Ethylester of Trinitrocarbamic Acid or
Picrylurethane. See Vol 2, pC43-R

Ethylester (Trinitro Deriv) of N,N'- Din-
itromethylendicarbamic Acid,

\[
\text{H}_2\text{N(NO}_2\text{)}_2\text{COO.CH}_2\text{C} = \text{N(NO}_2\text{)}_3
\]

\[
\text{CH}_2\text{N(NO}_2\text{)}_2\text{COO.CH}_2\text{C} = \text{N(NO}_2\text{)}_3
\]

mw 550.20, N 25.46%; crystals, mp 112°
ignition temp 218°, d 1.89 g/cc; impact sensitivity, ERL Machine with 2.5 kg wt & Type 12 tools = 10-20 cm for 50% exps. It was prepd by nitration of Trinitroethanol Ester of Methyleneedicarbamic Acid (qv) (Refs 1 & 2). Can be used as a solid ingredient in castable expls, analogous to use of RDX


N-Ethylester (Trinitro Deriv) of Ethanesulfonamide,

\[ \text{CH}_3 \cdot \text{CH}_2 \cdot \text{SO}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \cdot \text{H} \]

mw 272.20, N 20.58%; crys, mp 171°d 1.71 g/cc, ignition temp 281°, impact sensitivity, about that of Comp A or Torpex. It was prepd by add'g twice the theoretical amt of Trinitroethanol at 100° to the sulfonamide (Refs 1 & 2). Can be used as a solid ingredient in castable expls, analogous to use of RDX


bis- [Ethylester (Trinitro Deriv) ] of Fumaric Acid or bis (Trinitroethyl) Fumarate, CH. COO. CH._2. C(NO}_2)_3

\[ \text{CH}_2 \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

mw 442.18, N 19.01%; crys, mp 152°, d1.72 g/cc, ignition temp 227°, impact sensitivity - about that of Pentolite.

Prepd by treating the acid chloride with Trinitroethanol in the presence of AlCl_3 catalyst (Refs 1 & 2). Can be used as a solid ingredient in castable expls, analogous to use of RDX


Ethylester (Trinitro Deriv) of Methyleneedicarbamic Acid, \[
\text{NH} \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

\[ \text{CH}_2 \cdot \text{NH} \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

mw 460.19, N 24.35%; crys, mp 123°; d1.70 g/cc, ignition temp 205°, sensitivity by impact using ERL Machine with 2.5 kg wt & Type 12 tools = 40-20 cm.

Prepd by reaction of Trinitroethanol with Trinitroethyl Carbamate, or from methylenediisocyanate & Trinitroethanol (Refs). It can be used as a solid ingredient in castable expls, analogous to use of RDX

Refs: 1) Hercules Powd Co Progress Rept on Contract Nord 9925 (Aug 1950) 2) Aerojet Engrg Corp Quarterly Progress Rept 589 (March 1952)

Ethylester (Trinitro Deriv) of 2,5,5,8 - Tetranitro - 2,8 - diazoxanodioic Acid, CH, \_2 \cdot \text{HN(NO}_2)_2 \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

\[ \text{CH}_2 \cdot \text{CH}_2 \cdot \text{N(NO}_2)_2 \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

mw 696.31, N 24.14%; crys, mp 149-50°, d 1.76 g/cc, hot bar ignition temp 211°, sensitivity to impact - about the same as PETN. It was prepd by nitrating with 100% nitric acid the bis (carbamate) resulting from reaction of 3,3-dinitropentane-1,5-diisocyanate & Trinitroethanol. Can be used as a solid ingredient in castable expls, analogous to use of RDX


Ethylester (Trinitro Deriv) of N,N', 3,3 - Tetranitro - 1,5 - pentanedicarbamic Acid.

Same as above compd

bis-Trinitroethylester of Trinitroethylsuccinic Acid

\[ (\text{O}_2 \text{N})_3 \cdot \text{CH}_2 \cdot \text{OOC} \cdot \text{CH}_2 \cdot \text{COO} \cdot \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

\[ \text{CH}_2 \cdot \text{C(NO}_2)_3 \]

Ethylethanolamine. See Ethylaminoethanol in this vol.

Ethylethanolperoxide or Hydroxydiethyl Peroxide,
\[ C_2H_5OOCHOHCH_2 \quad \text{mw} \ 106.12 \text{ liq, spgr} 0.974 \text{ at } 21.4^\circC \text{ bp } 50-2^\circC (50 \text{ mm Hg}), \]
\[ n_D 1.4021 \text{ at } 21.4^\circC \text{ Prepd by letting stand for one day a } 5 \text{% eth soln of ethylhydroperoxide and acetaldehyde. If distilled in the presence of water, there is the danger of expln} \]

Refs: 1) Beil, not found 2) A. Riche, Ber 63B, 2642-52 (1930) & CA 25, 911 (1931)

Ethylether or Ether. See Diethyl ether in Vol 5, p D1233 of Encyd. See also Ether in this Vol

Ethyl Ether (Analytical). Its estimation in mixtures with ethanol, water and acetone is described in this Vol under "Ethanol Determination in Solvents Used in Manufacture of Smokeless Propellants" and also under "Ethanol Determination in Nitrocellulose and Smokeless Propellants"

Ethylethoxyphenylyurea and Derivatives
Ethylethoxyphenylyurea (N-ethyl-N'-4-ethoxyphenyl-harnstoff in Ger),
\[ C_2H_5NHCONHC_6H_4OC_2H_5 \quad \text{mw} \ 208.26 \]
cryst (benz), mp 152\(^\circ\), sol in alc, acet & warm benz. Prepd by reacting p-phenetidine with ethylisocyanate in eth at 0\(^\circ\)

Refs: 1) Beil 13, [254] 2) H.F.J. Loning, RecTravChim 46, 641 (1927)

Nitroethyl - trinitroethoxyphenylyurea
[N-nitro-N'-ethyl-N'-2,3,6-trinitro-4-ethoxyphenyl]-harnstoff, in Ger],
\[ C_2H_2N(NO_2)_3CONHC_6H_4(OCH_2CH_3) \]
\[ \text{mw} \ 388.25, N 14.43%, \text{OB to CO}_2 \]
\[-74.2\%, \text{yel crs, mp 92-8\(^\circ\)} (dec) \text{ sol in acet & benz. Prepd by treatment at -10 with 100\% HNO}_3, \]
N-ethyl-N'-ethoxyphenylurea. Decomposition occurs on attempted recrystallization from acet, benz, chl, or petr eth

Refs: 1) Beil 13, [295] 2) H.F.J. Loning, RecTravChim 46, 642 (1927)

Ethyl-N-ethylcarbamate. See Ethylurethane

Ethylethylene. See Butene or Butylene in Vol 2 of Encycl, p B373-R

Ethylethylen. Hydrazine. See Diethylhydrazine in Vol 5 of Encycl, p D1237-L
Its Hexanitro Derivative is described as N,N'-Di(2,2,2-trinitroethyl) hydrazine or 1,2-Bis(2,2,2-trinitroethyl) hydrazine on p D1237-R in Vol 5

Ethylformal Polysulfide (LP-33). Used, under the code name Unit No 533, as fuel in some rocket propellants
Refl: PropIntManual SP1A/M2 (1962) (Cont)

Ethylformate, HCOO.C.H.H mw 74.08; col, flammable, pleasant smelling liquid, sp gr 0.9236 at 20/20\(^\circ\) br p-80.5\(^\circ\), bp 54.3\(^\circ\), fl p-20\(^\circ\), nD 1.35975 at 20\(^\circ\), vapor pressure 200mm at 20.6\(^\circ\); soly in w 11% at 18\(^\circ\); with gradual decompa; miscible with alc, ether & benz. Can be prepd by heating ethanol with formic acid in presence of sulfuric acid. Can be used as solvent for cellulose nitrate and acetate; as acetone substitute and as fungigant
Ethylfuorurate or Ethyl Pyromucate,
\(\text{C}_4\text{H}_5\text{O}_2\text{CO}_2\cdot\text{C}_2\text{H}_5\); mw 140.13; wh lfts
or prisms, sp gr 1.1174 at 20.8/4\(^\circ\), mp
34\(^\circ\), bp 195\(^\circ\) at 766 mmHg, insol in w;
miscible with alc or ether. Can be prepd
by saturating a soln of fumaric acid in alc
with HCl
3) CondChemDict (1961), 470-R

Ethyl-\(\beta\)-furylacrylate (Furfuracrylate
d'ethyl, in Fr.),
\(\text{C}_4\text{H}_3\text{O}_2\text{CH}::\text{CH}:\text{COOC}_2\text{H}_5\); mw 166.18, liquid
sp gr 1.0891 (25/4\(^\circ\), mp 24.5\(^\circ\), bp 130\(^\circ\) at
20 mm, 233-35\(^\circ\) at 1 atm, n\(_D\) 1.5286 at 20\(^\circ\)
sol in alc & eth; insol in water. Was prepd
by esterification of furfural acyclic acid,
which in turn was prepd from furfural. Was tried
in France as a possible substitute for
centalite in solventless smokeless prods
(poudre SD, in Fr.), but found to be
unsatisfactory
Refs: 1) Beil 18, 300 2) R. Dalbert &
H. Ficherouelle, MP 30, 283-30 (1928)

Ethylglucopyranoside and Derivatives
Ethylglucopyranosides,
\(\text{OCH}::\text{CH}::\text{CH}::\text{CH}::\text{CH}::\text{COOC}_2\text{H}_5\)
\(\text{C}_4\text{H}_3\text{O}_2\text{CH}::\text{CH}:\text{CH}::\text{CH}:\text{CH}:\text{COOC}_2\text{H}_5\)
= mw 208.21, a-form: rh cryst (acet), mp 114.6\(^\circ\)
sol in w & hot alc; \(\beta\)-form: ndl(acet),
mp 73\(^\circ\), sol in w & alc. Prepn of a-form
by action of HCl on \(\beta\)-form, or by heating
d-glucose in alc containing HCl; prepn
of \(\beta\)-form by saponification of the tert-
acetate; also enzymatic preps of both from
d-glucose and alc
Refs: 1) Beil 31, (188) 2) E. Fischer,
Ber 28, 1153 (1895) 3) W. Koenigs &
E. Knorr, Ber 34, 972 (1901)
149 (1913)

Ethylglucopyranoside Tetranitrate,
\(\text{C}_4\text{H}_3\text{O}_2\text{NO}_4\); mw 388.20, N 14.43\%, OB
to CO\(_2\) 33.0\%, colorless ndl (alc), mp
99-100\(^\circ\), is sl sol in w. Prepd by reaction of ethylglucopyranoside with fuming nitric
acid in acetic anhydride at 0\(^\circ\) for one hour
Refs: 1) Beil 4, 575 2) A. Hantzsch &
W. V. Metcalf, Ber 29, 1683 (1896)
3) E. H. White & R. J. Baumgarten, JOC 29
(12), 3636-40 (1964)

Ethylglycerate,
\((\text{HO})\text{C}_4\text{H}_3\text{O}_2\cdot\text{C}_2\text{H}_5\); mw 134.13, liquid,
sp gr 1.191 at 15/15\(^\circ\), bp 121\(^\circ\) at 14 mmHg;
sol in w & in alc. Can be prepd by heating
glyceric acid with alc at 190\(^\circ\)
Refs: 1) Beil 3, 397, (141-2) & [264]
2) L. Henry, Ber 4, 706 (1871)

NOTE: No azido or nitro derivs were found
in the literature

Ethylglycinic and Derivatives
Ethylglycinic,
\(\text{H}_2\text{N}::\text{CH}::\text{COO}::\text{C}_2\text{H}_5\); mw 103.12, colorless
oil, sp gr 1.028 at 20/4\(^\circ\), fr p <20\(^\circ\), bp 148\(^\circ\)
at 748 mmHg, n\(_D\) 1.4242 at 20\(^\circ\) miscible with
w, alc or eth. Can be prepd by treating
glycine HCl in alc with HCl to get the
HCl salt, then shaking an ag suspension of
the salt with the proper amount of Ag\(_2\)O in
eth. Nitrous acid salt cryst (alc), dec
140\(^\circ\), sol in w, alc, chl, eth, & benz. Prepd
from HCl salt and silver nitrate; piconate,
prisms (w), mp 155\(^\circ\)
Refs: 1) Beil 4, 340, (467) & [780]
2) T. Curtius, Ber 16, 754 (1883)

N - Nitro - ethylglycinate
(Nitratoacetic acid ethyl ester in Get.),
mw 148.12, N 18.91\%, cryst (eth), mp 24-5\(^\circ\),
mpl. 4610 at 24\(^\circ\), sol in all organics. Prepd
by nitrating N-carboxyethyl ethyl glycinate
in the cold with nitric acid in eth to get the
N-Nitro-N-carboxyethyl compound, treating
the latter with ammonia gas to get the
N-nitro-N-ammonium salt, and finally acidi-
ifying with hydrogen sulfide. The ammonium
salts melts with dec at 60\(^\circ\), is sol in alc and
is very hygroscopic
Refs: 1) Beil 4, 575 2) A. Hantzsch &
W. V. Metcalf, Ber 29, 1683 (1896)
3) E. H. White & R. J. Baumgarten, JOC 29
(12), 3636-40 (1964)
Ethylglycinon Hydrochloride; Ethylglycine Hydrochloride; Ethylglycoll Hydrochloride or Glycine Ethylester Hydrochloride.

H₂N·CH₂·CO·CH₃·HCl; mw 139.58, wh to pale yellow needles, mp 140-144°, bp—sublimes; sol in w & alc. insol in hydrocarbons; decomposes by alkalis. Can be prepared by treating glycine hydrochloride in absolute alcohol with HCl gas followed by heating. Used in synthesis and in rocket propellants.


Ethylglycine Ethylester and Derivatives

Ethylglycine Ethylester or Ethyl-3-azavaletate, CH₃CH₂N·CH₂CO₂·CH₃; mw 131.18, liq, bp 38° (16mmHg). Prepd by treating ethylglycine with HCl in alc.

Refs: 1) Beil 4, [787]  2) A. Skita & C. Walff, Ann 453, 205 (1926)

N-2,2-Dinitroethylglicine Ethylester or Ethyl-3-aza-5,5-dinitrovalerate, CH(NO₂)₂CH₂·NHCH₂CO₂·CH₃; mw 221.17

N 12.66% (NO₂), yel plates (EtAc), mp 102-3° (dec). Prepd from the reaction of the sodium salt of 2,2-dinitroethanol with ethylglycine hydrochloride.


N-2,2-Dinitroethyl-3-nitroglycine Ethylester or Ethyl-3-aza-3,5,5-trinitrovalerate, CH(NO₂)₂CH₂·N·NO₂CH₂CO₂·CH₃;

mw 266.17, N 15.79% (NO₂). OB to CO₂—54.1%, crystals (CCl₄), mp 41.2°. Prepd by treating the 5,5-dinitro compound with HNO₃/H₂SO₄ at 0°, then raising temp to 55-60°. Treatment with NaOCH₃ in methanol gives the 5-sodium salt, it yel crystals dec at 87-88°.


Ethylglycocol Hydrochloride. See Ethylglycinon hydrochloride in this vol

Ethylglycolate and Derivatives

Ethylglycolate, HOCH₂·CO·CH₃; mw 140.10, colorless liq, sp gr 1.087 at 15/4°, bp 160°, v sol in alc & eth. It can be prepd by heating at 150° o-chloroethylacetate, sodium acetate and alc.

Refs: 1) Beil 3, 236,(91) & [171]  2) W. Heintz, Ann, 123, 326 (1862)

Ethylglycolate Nitrate, O₂NO·CH₂CO₂·CH₃; mw 149.10, OB to Co₂⁺ 69.8%; col liq, bp 180-2°, 75-7° (20mmHg), sp gr 1.249 at 20°, nD⁰ 1.478 at 20°. Prepd from ethylglycolate and HNO₃/H₂SO₄ (Ref 2) or more recently by using HNO₃ (HNO₃/Ac₂O) or 70/30 HNO₃/H₂SO₄ with α-1 or β-β-ethyl acetate at low temp (Ref 3). The compd expl on heating.


Trinitroethylglycolate Nitrate, (O·NO)₂²

CH₂-COO·CH₂·C(NO₂)₃; mw 284.10, N 19.73%; OB to CO₂⁺ 5.6%. There is no mention of this material in the open literature. Presumably prepd was by esterification of the free acid nitrate (which is known) with 2,2,2-trinitroethanol.

Refs: 1) Beil, not found  2) US Rubber Co Quarterly Rep No 25 on Contract Nos 10129 & 12663, Nov 1,1953-Feb 1,1954, pp 3 & 7

Ethylglycol Ether and Derivatives

Ethylglycol Ether, HOCH₂·CH₂·OC₂·H₅; mw 90.12, colorless liq, sp gr 0.935 at 15/15°, bp 134-5° (48 mmHg), sol in liq NH₃. Prepd by heating glycol, ethyl iodide and sodium.

Refs: 1) Beil 1, 467,(244) & [518]  2) M. H. Palomeca, Ber 42, 3876 (1909)

Ethylglycol Ether Nitrate

O₂·NO·CH₂·CO₂·H₅; mw 135.12, liq, sp gr
1.1118 at 20°, bp 64° (12 mm Hg); nD 1.4132 at 22°. Prepd by treating ethylglycol ether with HNO₃ /Ac₂O under 5° (Ref 2).


Mononitroethyglycol Ether or Nitroethoxyethanol
HOCH₂CH₂OCH₂CH₂NO₂; mw 135.12, liq, sp gr 1.2185 at 20°, bp 92° (3 mm Hg); nD 1.4516 at 20°. Prepd by heating 2-nitroethanol with ethylene oxide for 6 hours at 80° in the presence of sulfuric acid

Ethylglycolic Acid, Ethoxyacetic Acid or Glycolic Ethylether
C₇H₅O.CH₂.CO₂H; mw 104.10; colorless liq sp gr 1.102 at 20/4°, bp 206-7°, 128-30° (40 mm Hg); nD 1.4194 at 20°. Can be prepd by mixing chloroacetic acid and sodium ethoxide in alc

NOTE: No azido or nitrated derivs were found in the literature.

Ethylguanidine and Derivatives
Ethylguanidine
C₇H₅.N.H.C(=NH).NH₂; mw 87.125, N 48.23%; mp 210-12° (Ref 5). Prepd as various salts by reacting H₂N.C(=NH)SC₃H₇ with 30% alcoholic ethylamine or C₂H₅.NHC(=NH)SC₃H₇ with 25% ammonia; prepd as free base (apparently) by reacting H₂N.C(=NH)SC₃H₇ with EtNH₂ in NH OH (Ref 5). Heating ethylamine with CaCN₂ or NCHN(=NH)NH₂ gives the nitrate salt, mp 108-9° (Ref 3). Sulfate salts are obtained directly by heating H₂N.C(=NH)OEt. EtHSO₄ with ethylamine for 3 hours at 60° (Ref 4); picrate, mp 178-80° (Ref 2).


1-Ethyl-3-nitrosoguanidine
C₇H₅.NHC(=NH)NHNO₂; mw 116.12, N 48.25% 2 2
Prepd as the C₆H₄N₄NiO₂ salt, bright red powder, expl. Prepd by addition of Ni(NO₃)₂ and NaAc in w to the product from the Raney nickel/H₂ reduction of 1-ethyl-3-nitroguanidine (see below) (120 am H₂, ambient temp, CH₃OH solvent). The reduction product itself is extremely sol in w and alc, but does not recrystallize in a pure state from either
Refs: 1) Beil, not found  2) E. Lieber & G. B. L. Smith, JACS 59, 2283-7 (1937) & CA 32, 502 (1938).

1-Ethyl-3-nitroguanidine
C₇H₅.N(C(=NH)NHNO₂; mw 132.12, N 42.41% cubes, mp 147-8°, sol in alc, cold w & eth. Prepd from nitroguanidine and 10% aqueous ethylamine at 60-70° (Ref 2) or by treating the nitrate salt of ethylguanidine with sulfuric acid for 3 hours at 5° (Ref 3).

1-Ethyl-1-nitroso-3-nitroguanidine
C₇H₅.N(NO)(C(=NH)NHNO₂; mw 161.12, N 43.46% OB to CO₂ 64.6%, mp 114.5° (dec) (118° dec). Prepd by treating 1-ethyl-3-nitroguanidine with nitrous acid
1,1-Dinitro-2-guanidino-ethane
CH(NO₂)₂NHNC(=N)NH₂, mw 177.12,
N 39.54%, OB to CO₂ - 49.7%, gold plates
(w) mp 196-9 °. Prep'd by treating 1,1,1-
Trinitroethane at 0-5 ° with guanidinium carbon-
ate which has been reacted with NaOEt in alc.
Refts: 1) Beil, not found 2) L. Zeldin &
H. Shechter, JACS 79, 4708-16 (1957) & CA 52,
2735 (1958)

1-Nitro-3-(2,2,2-trinitroethyl)-guanidine or
Tetranitro-ethylguanidine
O₂N.H.C(=NH).NH.CH₂.C(NO₂)₃, mw
267.115, N 20.97%(NO₂), OB to CO₂ - 3.0%,
colorless crystals mp 164 °(168-170 °), bp ignites
at 200 °. Can be prep'd by the reaction of
nitroform with methylolnitroguanidine. (Refts
2-4). Other method is given in Ref 5, p.61.
It is an exp with sensitivity about that of
Tetryl and Vacuum stability at 100-11 ml of
gas per gram evolved in 48 hours. It may be
nitrated to Pentanitroethylguanidine
Refts: 1) Beil, not found 2) US Rubber Co,
3) Ditto, Progress Report No 6 (1949), pp.4-6
4) Ditto, Progress Report No 8 (1949), pp.23-4
5) ADL, Synthesis HE's, 2nd Report (1951)
pp.53 & 61 6) W.F. Sager & D.V. Sickman,
NAVORD Report 483 (1952), p.33. 'Research
and Development in New Chemical High Ex-
Plosives'
7) H. A. Hageman, USP 3035094
(1962, applied 1949) & CA 57, 8792 (1962)

1,3-Dinitro-3-(2,2,2-trinitroethyl)-guanidine
or Pentanitroethylguanidine
O₂N.H.C(=NH).N(=NO₂).CH₂.C(NO₂)₃, mw 312.11,
N 22.43%(NO₂), OB to CO₂ + 10.3%, colorless
crystals, mp ?. Can be prep'd by nitrating
1-Nitro-3-(2,2,2-trinitroethyl)-guanidine.
The compound is not mentioned in the open
literature
Refts: 1) Beil, not found 2) US Rubber Co,
Progress Report No 9 (1950), pp.19-21
3) ADL, Synthesis HE's (1951)

Ethylhexahydro Pyrimidine and Derivatives
5-Ethylhexahydro Pyrimidine
C(CH₃)₃ CHNH = CHNH = CH₂, mw 114.19.

This compound is not reported in the litera-
ture, nor is there an unsaturated version
Refts: 1) Beil, not found 2) CA, not found

5-Ethylhexahydro-5-nitro-pyrimidine
C(C₂H₅NO)₂CH(N(NO)(NO)CH(N)CH₂, mw 159.19
mp 159-60 °. Prep'd by heating for H/2 hours
at 95 ° a 1/3 mole ratio of nitropropane/formal-
dehyde/ammonia
Refts: 1) Beil, not found 2) T. Urbánski
et al, Roczniki Chem 28, 169-73 (1954) & CA 49,
8826 (1955)

5-Ethylhexahydro-5-nitro-1,3-dinitroso
Pyrimidine
C(C₂H₅NO)₂CH(NO)(NO)CH(N)CH₂, mw 217.19,
N 19.34%(NO₂), mp 116 °. Prep'd by
treating with 20% NaNO₂ the hydrochloride
salt of 5-nitro-2-ethylhexahydropyrimidine
Refts: 1) Beil, not found 2) T. Urbánski
et al, Roczniki Chem 28, 169-73 (1954) & CA 49,
8826 (1955)

Ethylhexahydro-triazine and Derivatives
1-Ethyl-2,4,6-triazine, (C₅H₅N.C₂H₅.NH.C₂H₅.NC₂H₅): mw 115.18.
This compound is not reported in the litera-
ture, nor is there an unsaturated version
Refts: 1) Beil, not found 2) CA, not found

3,5-Dinitro-1-ethyl-2,4,6-triazine
(C₅H₅N.C₂H₅.N(=NO₂).CH₂N(NO₂).CH₂),
w 205.17, N 13.65%(NO₂), wh crysts, mp 88-89 °
(Ref 2), 96-7 °(dec, Ref 3). Can be prep'd from
methyldinitramine, 40% of formaldehyde and
ethylation at 0 °
Refts: 1) Beil, not found 2) F. Chapman
et al, JCS 1949, 1639-40 & CA 44, 1412
(1950) 3) R. Reed Jr., JACS 80, 439-44
(1958) & CA 52, 10110 (1958)

2-Ethyl-1,3-hexanediol, 2-Ethyl-1-propyl-1,3-
propanediol or Ethexadiol
C₆H₁₃(CH(OH)).CH(C₆H₅).CH₂OH; mw 146.23,
nealy colorless, odorless, somewhat viscous,
hygroscopic liquid irritating to eyes, sp gr
0.9422 at 20/20 °, fr p-sets to a glass at -50 °.
bp 244° at 760 mm, 133° at 15 mm, nD 1.4511 at 20°, viscosity (absol) 323 cps, vapor pressure <0.01 mm at 20° (Refs 4 & 5). Fip (Cleveland open cup) 265° F; sol in alc & in eth; soln in w. Was first prep in 1928 by Grignard & Fluchaire (Ref 2 & 4), in two steps: 1) Condensation of butyraldehyde with ethoxy magnesium iodide to produce 2-ethyl-1,3-hexanediol di-butrate and 2) Saponification of this diester. In 1943 Kulphinski & Nord (Ref 3 & 4) prep 2-ethyl-1,3-hexanediol by hydrolyzing its monobutyrine, which was previously obtd by the reaction of butyraldehyde with magnesium aluminum butoxide. Carbide & Carbon Co produced it commercially by the hydrogenation of butyraldol (Ref 4, p 286).

It is severely toxic when taken orally, but can be applied to human skin without irritation or sensitization (Ref 4, p 323-24). High purity 2-ethyl-1,3-hexanediol is considered as one of the best insect repellants. It was used in great quantities during WWII against mosquitoes, black flies, gnats, chiggers, and other biting insects (Ref 4, p 286); it has also been used as a cosmetic ingredient and as a vehicle and solvent in formulation of printing inks (Ref 5). No info about its use in Indochina. Typical specification for commercial product and tests are given in Ref 4, pp 346-50.


2-Ethylhexanol. See 2-Ethyl-3-propylacrolein.

Ethylhexic Acid and Derivatives

2-Ethylhexic Acid

C₇H₁₅.CH(C₆H₅).COOH; mw 144.22, mild-odored liq, sp gr 0.9707 at 20/20°C, fr 1.036, bp 226.9°, vapor pressure 0.03 mm at 20°, sol in w. Can be prep'd by oxidizing the corresponding aldehyde. Used as a presciude and herbicide. Its metallic salts, especially of Pb, Mn, Co & Zn, are used as paint and varnish driers; its salts of light metals such as of Li, Mg, Ca & Al can convert some mineral oils to greases. Al salt is an excellent gelling agent for liquid hydrocarbons, such as gasoline and other petroleum fractions. High mol wt esters of this acid are used as plasticizers.


2-Ethylhexyl Acetate or Octyl Acetate

CH₃.COO.CH₂.C₂H₅(C₂H₅)₇; mw 172.26; colorless stable liq, sp gr 0.873 at 20/20°C, fr 0.93°, bp 199° 95° at 25 mm flp 180°F, nD 1.4204 at 20° vapor pressure 0.4 mm at 20°, viscosity 0.0154 poise at 20°, sol in w, miscible with alc. Can be prep'd by reacting 2-ethylhexanol with acetyl chloride. Used as solvent for NC, resins, lacquers and baking finishes.


2-Ethylhexyl Acrylate

CH₂.CH₂.COO.CH₂.C₂H₅.C₂H₅; mw 184.28, colorless liq with pleasant odor sp gr 0.8869, fr p -sets to glass at -90°C, flp 180°F, bp 85° (8 mm Hg), nD 1.4365 at 20° vapor pressure 0.1 mm at 20°, insol in w; sol in org solvents. It can be prep'd by treatment of methyl acrylate with 2-ethylhexanol. Used for plastics, protective coatings and water-based paints. Rohm & Haas Co proposed it as fuel-binder in some propellants, such as Unit No600 described in conf Propellant Manual SPIA/M2 (1962).

2-Ethylhexyl Alcohol, 2-Ethylhexanol or Octyl Alcohol
CH₃(CH₂)₇CH(CH₃)₂CH₂OH; mw 130.22; colorless, sl viscous liq, sp gr 0.83 at 20/20°, fr p >-76°; bp 183.5°, nD 1.4300 at 20°, fl p 81°C, vapor press 0.36 mm at 20°; sl sol in w; miscible with org solvents. Can be prep by aldolization of acetaldehyde or of butylaldehyde, followed by hydrogenation. Used in solvent mixts for NC, paints, lacquers; as defoaming & wetting agent and in organic synthesis (Ref 3).

Ethyl Hydrocraylate and Derivatives
_Ethyl Hydrocraylate_  
HO.CH₂.CH₂.COOC₂H₅; mw 118.13; colorless, liq, sp gr 1.064 at 25, bp 185-90°, 81° (13 mm Hg), nD 1.4271 at 23°, miscible with w, alc & eth. Can be prep by condensing polyoxyethylene with ethylbromooacetate and zinc in half and half eth and EtAc.

_Ethyl 2-Nitrohydrocraylate_  
HOCH₂.CH₂.NO₂CO₂C₂H₅; mw 163.13, sp gr 1.2662 at 20°, bp 102-3°(22 mm Hg), nD 1.4482 at 20°, dec on heating. Prepd by reacting formaldehyde with ethyl nitroacetate and NaAc at -15°.
& CA 62, 11702 (1965) 3) See also CA 69, 105825 (1968) for a sodium deriv.

_Ethyl Nitratohydrocraylate_  
O.NO₂CH₂.CH₂.CO₂C₂H₅; mw 163.13, sp gr 1.262 at 20°, bp 92-3°(11 mm Hg), 60-4°(1.5 mm Hg), nD 1.4258 at 25°, exp on dist at 760 mm Hg.
Prepd by electrolysis of a mixture of KNO₃ and potassium ethylsuccininate (Ref 2), or by treating AgNO₃ with ethyl 3-bromopropanoate in acetonitrile (Ref 3)

Refs: 1) Beil, not found 2) Fr. Fichter & W. Steinbuch, HelvChimActa 26, 695-704 (1943) & CA 37, 5699 (1943) 3) A.F.Ferris et al, JACS 75, 4078 (1953) & CA 49, 8157 (1955)

Ethyl Hydrazine and Derivatives
_Ethyl Hydrazine_  
C₂H₅.NH.NH₂; mw 60.10, N 46.61%, hy gr liq, bp 101°, very sol in w, alc or eth. Can be prep by reducing ethyl nitramine with zinc and HCl.

2,2-Dinitroethyl Hydrazine  
(O₂N)₂CH₂.CH₂.NH.NH₂ ; mw 150.095, N 2 2 2 2 2 2 2 2 37.33%, OB to CO₂ 32.0%, mp 137-140°,
sp gr 1.679, sol in dimethyl sulfoxide & hot w. Prepd by reacting 2,2-dinitro-1,3-propanediol with hydrazine acetate in alc. The Olin-Mathieson Drop Test value for impact sensitivity is 21 kg cm.
Refs: 1) Beil, not found 2) J.M. Greendorfer, USP3314997 (1967) & CA 67,73313 (1967)

_Ethyl Hydride._ Same as Ethane

Ethylhydroperoxide and Derivatives
_Ethylhydroperoxide_  
C₂H₅.O₂H; mw 62.07, colorless liq, fr p about 100°, bp 41-42° at 55 mm Hg, nD 1.3608 at 20°, miscible with w, alc or eth. Was first prepd in 1901, together with diethylperoxide, by Baeyer & Villiger (Refs 1 & 2) from diethyl sulfate and alkaline soln of hydrogen peroxide (See also Ref 3). Can also be prepd by treating ethyl chloride, ethyl sulfate or ethanol with H₂O₂ in presence of strong acids (See also Refs 4,5,6, & 7). It is a strong oxidizing agent and easily explodes on heating or on impact, even when in soln.

_Ethylhydroperoxide Salts._ Several salts are known, some of them explosive. Its _Barium Salt_, Ba(OO.C₂H₅)₂+2H₂O, consists of prisms
E 301

easily sol in w and insol in alc. Explodes on heating
Refs: 1) Beil 1, 323 & [324] 2) A. Baeyer & V. Villiger, Ber 34, 738 (1901) 3)
A. Riche & F. Hitz, Ber 62, 245 (1929) 4) E. J. Harris, Proc Roy Soc A173, 126 (1939)
5) N. Milas, USP 2176407 (1939) 6)
A. C. Egeron et al, "Faraday Sociey Discussion on Hydrocarbons" 10, 278 (1951)
7) Tobolsky & Mesrobian (1954), pp 155 & 177

Ethyl Hydroxyacetamide
HO.CH₂.CO.NH.C₂H₅; mw 103.12, N 13.58%; oily liq, bp 127-129° at 2.5 mm Hg, sol in w, alc & eth. Was prep'd by mixing ethyl chloroacetate and alc ethylamine in the cold
Note: Attempts to nitrate it by dissolving 2 g of oil in 10 ml of white nitric acid, heating the soln to 50-60° for 30 minutes and then pouring into ice water, produced an oil. This oil gradually disappeared on standing, probably due to hydrolysis
Refs: 1) Beil, 4, 125 2) W. Heintz, Ann 129, 29 (1864)

Ethylhydroxyaniline. See N-Ethylaminophenol in this Vol

2-Ethylhydroxy-iso-butyrate
(CH₂)₂CO(OH)CO.C₂H₅; mw 132.16, colorless liq, bp 0.978-0.986 at 20°, fr p, bp 149-150° sol in w, alc or eth; decomp'd by hot w. Can be prep'd by heating ethyl iodide with the potassium salt of alpha-hydroxy-iso-butyric acid at 120-130°. Used as a solvent for NC & cellulose acetate and in organic synthesis.

Ethyl-1-hydroxyethyl Peroxide
₃C₂H₅.OC(OH).OOC.C₂H₅; mw 106.12, oily liq, sp gr 0.974 at 21.4°, bp 50-52° at 50 mm Hg, nD 1.4021 at 20°. Can be prep'd by mixing acetalddehyde and ethylhydroperoxide in eth

Ethylhydroxymethyl Peroxide
CH₂(OH).OOC.CH₃; mw 92.09, oily liq, sp gr 1.045 at 16/4°, bp 46-48° at 13 mm, nD 1.404 at 16°, sol in w; decomp'd on standing; very sol in alc & in eth; sol in benz. Can be prep'd by interaction of equivalent quantities of ethylhydroperoxide and formaldehyde in ethereal sn. Puffs off weakly on heating
Refs: 1) Beil, not found 2) A. Riche & F. Hitz, Ber 63, 2646 (1930) & A 25, 911 (1931) 3) Tobolsky & Mesrobian (1954), 173

Ethylhydroxyethyl-propanediol and Derivatives
2-Ethyl-2-(hydroxymethyl)-1, 3-propanediol or 2, 2-Di(hydroxymethyl)-butanol
C₆H₅.CH₂.OH₂.CH₂.OH; mw 134.18, wh plates hyg, mp 58.8-59°, bp 160° (5 mm Hg); very sol in w & alc; sol in acet. Prepd from butyraldehyde and formaldehyde in CA (OH)₂ solution. Used extensively to make polyurethane resin foams

2-Ethyl-2(hydroxymethyl)-1, 3-propanediol Dinitrate
C₆H₅.C(CH₃ONO)₂.OH; mw 224.17, N 12.50%, OB to CO₂, 78.6%. Prepd in 88% yield from
2-ethyl-2(hydroxymethyl)-1, 3-propanediol, urea, 1, 3-dichloropropene, 75% nitric acid and 75% sulfuric acid at -15°. No props are given
Refs: 1) Beil, not found 2) F. Krupp, Ger P1160427 (1964) & CA 60, 9150 (1964)

2-Ethyl-2(hydroxymethyl)-1, 3-propanediol Trinitrate or 2, 2-Di(hydroxymethyl)-butanol Trinitrate,
**C₄H₅(CH₂ON₃)₂CH₂O₃;** mw 269.17, N 15.61%, OB to CO₂ 50-55%, when powdd, mp 51°,
sp gr 1.48-0.50 (cast), sol in acet. Prep'd by nitrification of 2-ethyl-2-(hydroxymethyl)-1,3-
propanediol (Ref 3,6). Detonation velocity in 3-cm diameter cartridge at 1.48-1.50
g/cc 5300m/s cast, 7050 m/s compressed;
expln temp is 220° (compared with 215° for
PETN and 210° for NG in same apparatus),
heat of comb at Cᵥ is 829.2 kcal/m; impact
sensitivity is 3.6 kg/m; power by Pb block
115-5%.
Refs: 1) Beil, not found 2) H.Henkin &
R.McGill, IndEngChem 44, 1391-5 (1952) &
CA 46, 8857 (1952) (Expln temp) 3) L.
L.Méard, MP 35, 113-15 (1953) & CA 49,
6055 (1955) 4) L. Méard & M. Thomas, MP
35, 155-73 (1953) & CA 49, 11284 (1955)
5) L. Méard, MP 36, 8792 (1954) & CA 50,
6793 (1956) (Expl props) 6) G. Bouriol,
MP 36, 79-85 (1954) & CA 51, 10371 (1957)

**Ethylhypochlorite, C₂H₅.O.CI;** mw 80.52, yel
volatile liquid, sp gr 1.013 at -6/4°, bp 36°
at 752mm; explodes at high temp, violently
explodes by action of direct sunlight; miscible
with ether, benz & chlf. Can be prep'd by the
action of chlorine on ethanol (precooled to
-18°) in presence of aq soln of NaOH. It is
unstable.
Refs: 1) Beil 1, 324, (164) & [325] 2)
T.Sandmeyer, Ber 18, 1768 (1885)

**Ethylhyponitrite.** See Diethylhyponitrite
in Vol 5 of Encycl, pD1238-L

**Ethylidene Acetobenzoate and Derivatives**

**Ethylidene Acetobenzoate or Ethylidene Benzo-
acetate (Benzoat des Acetoin in Ger)
C₉H₈CO₂CH(COCH₃)CH₃,
mw 192.22, cedar-scented liq, sp gr 1.104
at 18°, bp 140-1°(8mm Hg). Prep'd from
acetoin and benzoylchloride in pyridine.
Can be prep'd commercially by interaction of
benzoic acid and vinyl acetate in presence of
catalysts. Used as solvent for NC₉ cellulose
acetate and natural & synthetic resins
Refs: 1) Beil 9, 149 2)O.Diels & E.Stephen,
Ber 40, 4340 (1907) 3)CondChemDict (1961),
472-L

**Ethylidene Aceto-3,5-dinitrobenzoate,
C₈H₇[3,5-(NO₂)₂]CO₂CH(COCH₃)CH₃;** mw
292.21. Presumably prep'd from acetoin and
"3,5-dinitrobenzoic acid", no props given
Refs: 1) Beil, not found 2)K.Maček et al,
Collection CzechChemCommun 29, 311-15
(1964) & CA 60, 6216(1964)

**Ethylidene Acetone, Methylpropenyl Ketone
or 3-Pentene-2-one, CH₃.CH.CH.CH₂.CO.CH₃;
mw 84.11, col liq, sp gr 0.856 at 20°, bp
122-124° at 745mm, sol in w. Can be prep'd
by heating pentanol-4-2-one at 250°
Refs: 1) Beil 1, 732,(381) & [179] 2) L.
Claissen, Ber 25, 3166(1892) 3) Sax, 3rd edit
(1968), p 999-R (3-Pentene-2-one)

**Ethylideneaminoguanidine and Derivatives**

**1-Ethylideneaminoguanidine,
CH₃.CH:NH.C(=NH)NH₂;** mw 100.12,
N55.96%. Prep'd from aminoguanidine and
acetaldehyde in the usual way of making a
hydrazone; no props given
Refs: 1) Beil, not found 2) P.Grammatikas-
tis, BullSocChimFr 1952, 446-538 & CA 47,
3817 (1953)

**Ethylideneaminoguanidine Nitrate**

**CH₃.CH:NH.C(=NH)NH₂.HNO₃;** mw 163.14,
N 42.93%, OB to CO₂ 73.6%, pr (alc), mp 140°.
Prep'd from HNO₃ and the free base
Refs: 1) Beil, not found 2) P.Grammatikas-
tis, BullSocChemFr 1952, 446-538 & CA 47,
3817 (1953) (Infrared spectrum)

1-Ethylideneamino-3-nitroguanidine,

**CH₃.CH=N NH.C(=NH)NH₂.HNO₃;** mw 145.12,
N 48.26%, mp 234°(Ref 2) 144-5°(Ref 4).
Prep'd by reacting acetaldehyde and nito-
aminoguanidine with a little acetic acid
Refs: 1) Beil, not found 2) G.B.L. Smith &
E.P. Shoub, JACS 59, 2078(1937) & CA 32,
118 (1938) 3) E.Lieber et al, AnalChem 23,
1594-1604 (1951) & CA 46, 3857(1952)(Infra-
red spectrum) 4) R.A. Henry & G.B.L. Smith,
JACS 74, 278 (1952) & CA 47, 8020 (1953)
Ethylidene Aniline and Derivatives

Ethylidene Aniline, CH₂=NCH₃; mw 117.19, N 11.76%; dark red-brown viscous liq, sp gr 1.27, bp 205 ⁰C insol in w, sol in gasoline & benz. Can be prepd by the action of acetaldehyde on aniline, followed by distillation. Used as accelerator in rubber vulcanization.

β-Nitroethyldiene Aniline, O₂NCH₂.CH=N₆H₃; mw 164.16, N 17.07%; ndl (benz) mp 94-5 ⁰C (sinters at 90 ⁰C). Prepd from aniline.HCl and acidified methazone acid.
Refs: 1) Beil 12, 188 & [110] 2) W. Meister, Ber 40, 3447 (1907)

Ethylidene -2,4-Dinitroaniline,
CH₃.CH=NC₆H₄(NO₂)₂; mw 209.16
N 20.09%, yel ndl (w/alc), mp 196 ⁰C, sol in 20% HCl & dil alkali. Prepd from boiling with IN NaOH the triethylamine salt of HO₂C.CH(2,4- dinitranilino) CH₃(2,4-dinitrophenol) - the amine salt of O,N-bis(2,4-dinitrophenyl) serine - and then acidifying. The compd may actually be N-vinyl-2,4-dinitroaniline, but the authors made no attempt to find out.

β-Nitroethyldiene-4-Nitroaniline,
O₂NCH₂.CH=NC₆H₄(NO₂); mw 209.16, N 20.09% ndl (clhf), dec 183 ⁰C. Prepd from 4-nitroaniline and methazone acid.
Refs: 1) Beil 12, 717 2) W. Meister, Ber 40, 3447 (1907)

Ethylidene Benzoacetate. See Ethylidene Acetobenzoate in this Vol

Ethylidene Chloride or Ethylidene Dichloride. See Dichloroethane in Vol 5 of Encycl, p D1209-R

Ethylidene Diacetamide, CH₃CH(HN.CO.CH₃)₃; mw 144.17, N 19.43%; col pr, mp 169 ⁰C (Refs 2 & 6) 180 ⁰C (Refs 3, 6, 8), sp gr 1.231. Prepd by heating in a sealed tube acetamide and acetamide (Ref 2); later by refluxing the same with HAc (Ref 3), then using acetonitrile and acetamide (Ref 6), and diethylcarbonate/acetamide (Ref 7). Attempted nitratin at 15 ⁰C with HNO₃/Ac₂O was a failure (Ref 4)

It's nitratin was conducted in A.D. Little laboratory in the following manner (Ref 5): To the stirred soln of 1.44g (0.01 mol) of ethylidene diacetamide in 4ml (0.04 mol) of acetic anhydride contd in a 25-ml Erlenmeyer flask (cooled in ice-HCl bath) was added dropwise 1.26g (0.02 mol) of absolute nitric acid. The resulting pale-blue soln was poured over 25g of cracked ice and the resulting soln was neutral by addn of Na carbonate. This soln was yellow in color but no ppt was obtd.

When attempted nitratin was conducted at temp of ice-water bath, a fume-off resulted after all the amide was added to the nitratin soln.

Ethylidene Diacetate or Diacetoxethane, CH₃.CH(O₂C.CH₃)₂; mw 146.145, col liq, sp gr 1.061 at 12 ⁰C, mp 18-85 ⁰C, bp 168 ⁰C at 740mm; sl sol in w, miscible with alc, decmpd by alkalis. Can be prepd by heating acetaldehyde with acetic anhydride at 180 ⁰C. Used for making acetic anhydride and vinyl acetate.
Refs: 1) Beil 2, 152, (71) & [167] 2) A. Geuther, Ann 106, 250 (1858)

Ethylidene Dichloride. See Dichloroethyldene in Vol 5, p D1209-R
Ethylidene Diethyl ether. See Acetol in Vol 1 of Encycl, p A13-I.

Ethylidene Difluoride or 1,1-Difluoroethane, CH₃CHF₂; mw 66.05; col., odorless gas, sp gr 1.004 at -25°C, fr p -117°C, bp -24.7°C, insol in w. Can be prepd by adding hydrogen difluoride to acetylene. Used as aerosol propellant, refrigerant and intermediate

Ethylidene Dimethyl ether or Dimethylacetel, CH₃CH(OCH₃)₂; mw 90.12; col., flammable, liq, sp gr 0.850 at 20/40°C, fr p -113.2°C, bp 64°C at 748mm; miscible with w, alc., eth & chf. Can be prepd by heating acetaldehyde with methanol & glacial AcOH, followed by distillation and rectification. Used in medicine and in organic synthesis

Ethylidene Dioxide. Misnomer for Diethylidene Dioxide described in Vol 5 of Encycl, p D1238-L.

Ethylidene Diurethane, CH₃CH(NH₂CO₂C₂H₄); mw 204.22, N 13.72%; ndls, mp 120-121°C (Nenciti); mp 125-126°C (Lange), bp 170-180°C at 20mm, sol in alc, eth and hot w. Was first prepd in 1874 by interaction of acetaldehyde and urethane (Refs 1 & 2)
ADL, Inc (Ref 3) prepd it by shaking in 250-ml flask: 35.6g (0.4mol) of urethane, 8.9g (0.2mol) of acetaldehyde in 200ml distd w congn 0.6mol of concd HCl and allowing to stand for 24 hours. Then the ppt was collected and recrystallized from water
Nitrated was attempted by adding drop by drop with stirring, 4.08g (0.02 mol) of ethylidene diurethane into a flask (cooled in ice-HCl bath), congn 2.5g (0.04 mol) of absol nitric acid mixed with 8.0g (0.08 mol) of acetic anhydride. During addition it was necessary to wait until each drop dissolved before the addition of next drop. After adding all 4.08g of ethylidene diurethane, the soln turned blue and at that moment it was poured over cracked ice. As result of this an oily paste settled at the bottom of vessel contg ice. Extraction with ether gave 1.6g of pasty solid product melting at 118.5-119.5°C. A mixed mp with Ethylidene Diurethane showed no depression
Note: It is necessary to pour the nitrated liquid over ice, immediately after it becomes blue because delay will cause its decomposi- tion with vigorous evolution of gas and loss of product
Refs: 1) Beil 3, 24 (11) 2) M. Nenciti, Ber 7, 160 (1874) 3) ADL, Synthesis HE's, 2nd Report (1951), 54-5

4,6-Ethylidene-methylglucosides and Derivatives

Ethylidene-α-methylglucose
\[ \text{C}_6\text{H}_5\text{O}(\text{CH}_3\text{)}\text{CHOHCH(OCH}_3\text{)}\text{CH}\text{OCH(C}_2\text{H}_4\text{)} \];
mw 220.22, mp 77°C. Prepd by reacting acetyl-
ene with α-methylglucose in EG under 10°C in the presence of HgSO₄ and H₂SO₄
Refs: 1) Beil, not found 2) H.S. Hill & H. Hie-
bert, JACS 45, 3108-3116 (1923) & CA 18, 1987 (1924) 3) B. Helferich & H. Appel, Ber 64B, 1841-7 (1931) & CA 25, 5401 (1931)

4,6-Ethylidene-β-methylglucose, see formula above; mw 220.22, ndls, sp gr 1.40, mp 182-83°C. Prepd by hydrolysis with NaOH in chf of diacetylidene-β-methyl-d-glucoside, which was prepd from β-methylglucoside, Ac₂O & pyridine
Refs: 1) Beil, not found 2) B. Helferich & H. Masamune, Ber 64B, 1257-60 (1931) & CA 25, 5147 (1931) 3) H. Appel & W. N. Haworth, JCS 1938, 793-7 & CA 32, 6626 (1938)

4,6-Ethylidene-α-2/methylglucoside Nitrate
\[ \text{C}_6\text{H}_5\text{O}(\text{CH}_3\text{)}\text{CH(ONO}_2\text{)}\text{CHOHCH(OCH}_3\text{)}\text{CH}_2\text{OCH(CH}_2\text{)} \];
mw 265.22, N 5.28%, ndls (alc+petr eth), mp 133°C. Prepd by refluxing the α-2,3-dinitrate (see below) in alcoholic hydrazine
Refs: 1) Beil, not found 2) K. S. Ennor & J. Honeyman, JCS 1958, 2586-94 & CA 52, 19960 (1958)
4.6-Ethylidene-β-2-methylglucoside Nitrate, see formula for α; mw 265.22, cryst, mp 144°. Prepd by refluxing the β-2,3-dinitrate (See below) in alcoholic hydrazine.
Refs: 1) Beil, not found 2) K. S. Ennor & J. Honeyman, JCS 1958, 258-94 & CA 52, 19960 (1958)

4.6-Ethylidene-α-3-methylglucoside Nitrate, OCH(CH₃)CHOHCH₂(NONO₂)CHCH₂OCH(CH₃)O mw 265.22, N 5.28%; mp 172-3°. Prepd by alkaline hydrolysis of the α-2,3-dinitrate (See below).
Refs: 1) Beil, not found 2) E. G. Ansell & J. Honeyman, JCS 1952, 2778-89 & CA 47, 1066 (1953)

4.6-Ethylidene-β-3-methylglucoside Nitrate, see formula for α; mw 265.22, mp 146-8°. Prepd by heating the β-2,3-dinitrate (See below) for 1 hr at 100° in a sealed tube with Na and acet.
Refs: 1) Beil, not found 2) D. J. Bell & R. L. M. Syne, JCS 1938, 833-6 & CA 32, 6627 (1938)

4.6-Ethylidene-α-2,3-methylglucoside Dinitrate, OCH(CH₃)CH(NO₂)CH(NO₂)CHCH₂OCH(CH₃)O; mw 310.22, N 9.03%; mp 96-7° (Ref 2), 101° (Ref 3). Prepd by addition of the parent in chlf to N₂O₄ in chlf at 0°. Later prepd by adding to the parent in Ac₂O at 0°, fuming HNO₃ in Ac₂O (Ref 3).

4.6-Ethylidene-β-2,3-methylglucoside Dinitrate, see formula for α; mw 310.22, N 9.03%; ndls (pet eth or CH₃OH), mp 88-9°. Prepd by addition of the parent in chlf to N₂O₄ in chlf at 0°. Later prepd by adding fuming HNO₃ in Ac₂O to the parent in Ac₂O at 0° (Ref 3).

Ethylideneperoxide (Athylideneperoxyd in Ger) (Was called by Baeyer and Villiger Acetaldehydeperoxyd or Dicetaldehyd-diperoxid and by Wieland and Wingler, Diathyliden-diperoxid, \( \left[ \text{H}_3\text{C} \right. \begin{array}{c} \text{CH} \vdash \text{C} \vdash \text{O} \end{array} \left. \text{H}_3\text{C} \right] \))

bp-empl violently when heated in a closed tube; does not seem to be sensitive to friction; insol in water, easily sol in eth, more difficulty in alc, still more difficulty in benz and very diff in petroleum ether. When left standing for several hours in a closed container, the oily substance changes into a tough tar, extremely sensitive to impact and friction.

The following discussion is mainly historical and indicates the confusion generated by non-analyzable materials.

Two modifications were prepd and closely examined before WWII by Rieche and Meister (Ref 4). Among the several methods of preparation, they recommended the one from an ethereal solution of α-hydroxyethylhydroperoxide (α-Oxyathylhydroperoxide-in Ger) and \( \text{P}_2\text{O}_5 \).

A compound which closely resembled the tarry substance was prepd in 1900 by Baeyer and Villiger by adding 0.1 g of acetaldehyde to a mixture of 1 g \( \text{H}_2\text{O}_2 \) (10% sol) and 2 g \( \text{SO}_3 \), cooled to 0°. The oil which separated on standing gave, on cooling in ice, a volatile solid which exploded violently on impact or heating. They called the compound Dicetaldehydperoxyd, but did not determine its composition.

A substance closely resembling the oil produced by Rieche and Meister was prepd previous to them by Wieland and Wingler (Ref 3) by treating freshly distilled acetaldehyde with an ethereal solution of anhydrous \( \text{H}_2\text{O}_2 \). It exploded on heating in a closed container. W&W called it Dithialiden-diperoxid and assigned the formula:

\[ \text{H}_3\text{C} \vdash \text{C} \vdash \text{O} \]

\[ \text{CH}_3 \]
It might also be called Diacetaldehydediperoxide or Acetaldehydedeperoxide.

The chemical properties of ethyldieneperoxide are given in Ref 4.

Rohrlich and Sauerimlich (Ref 5), in an article on Tricyclooctaneperoxide, said that they determined the lead block expansion for a 10 g sample of the "Azetaleydhyd" of Baeyer and Villiger. The value was 330 cc as against 250 cc for Tricyclooctaneperoxide. They also stated that when a test tube with a sample of Acetaldehydedeperoxide was dropped on the floor from a height of 2 m, a violent detonation took place. The same authors stated that they could not determine the velocity of deton of acetaldehydedeperoxide because it was very dangerous to handle. (Compare with Diethylene Diperoxide, described in Vol 5 of Encycl, p D1239-L)


**Ethyldene Peroxide, DimERIC,**

CH₃CHOOC(CH₂OH)₆O₂; mw 120.11, ndls, mp 63°, extremely vol; sol in organics; insol w. Prepd by heating at 60-70° and 14 mm Hg dimeric triethylene ozonide (Ref 4 above). C-H analysis gave correct empirical formula while molecular weight determination gave 117 in benz and 123-7 in dioxane. Stable at 100°, doesn't liberate much [8] during iodometric titration. Authors of Ref 2 believe that no “monomer” exists only the dimer and polymers, and consider the "dimer" of Ref 3 above to be the polymer. Absolutely minimal quantities must be prepd because of its unpredictable deamination.


**Ethyldene Peroxide, Polymeric, (CH₃CHOO-)₄, mw (60.05)₁, viscous oil, sp gr 1.160-1.165, nD1 1.451 at 19°. Prepd by treating CH₃CHOH₃OOH or [CH₃CH(OH)O]₁₂ with P₂O₃, using heat with the latter ether. The freshly prepd material is fairly safe to handle, but rapidly in air, and in a few days in a closed container, becomes highly sensitive to contact with a glass rod (but, strangely, not to the shock of the detonation caused thereby-only the contact material goes off).


**Ethyl Lactate and Derivatives**

**Ethyl Lactate.** CH₃CHOHCOOC₂H₅; mw 118.13; col, oily liq, with mild odor; sp gr 1.030 at 25/4°, bp 154-155°, fl p (Tag open cup) 158°F; miscible with w, alc, eth, esters, ketones, hydrocarbons & oils. Was prepd from Etl and the silver salt or by heating the acid with alc at 170° in a closed tube. Two methods of prepn are listed in Ref 3: a) By esterification of lactic acid with ethanol and b) By combining acetaldehyde with hydrocyanic acid to form acetaldehyde cyanohydrin, and this is treated with ethanol & HCl to ethyl lactate. Used as a solvent for cellulose acetate and nitrate, other cellulose esters, resins, lacquers, paints and enamels.


**Ethyl Lactate Nitrate.** CH₃CHO(ONO₂)₂CO₂C₂H₅; mw 163.13, N₈.59%; liq, sp gr 1.1824 at 20/4°, bp 73-40° (10mmHg), 178°, nD1 1.4155 at 20°. Prepd from the parent and mixed nitrating acid.
(Ref 2), later from the 2-bromo ester and silver nitrate in acetonitrile (Ref 3), by oxidizing 1-nitropropane-1 with nitric acid followed by esterification (Ref 4), by reacting silver nitroform with the 2-bromoester (Ref 5) and by reacting the 2-bromo iodooester with nitric acid (Ref 6).


**Ethyl-2-Nitroacetate Nitrate**

CH₃(NO₂)KONO₂CO₂C₂H₅; mp 208.13, N₃.46%, OB to CO₂-53.4%; bp 80° (0.1mm Hg), nD¹ 1.4432. Prepd by addition of HNO₂CH₂CH₃CO₂C₂H₅ to 100% HNO₃ at 0°, then letting stand one day at ambient temp.


**Ethyl-3-Nitrolactate, CH₃(NO₂)CNHOOC₂C₂H₅;**

mp 163.13, M₈.59%, liq, bp 100° (4mm Hg), nD¹ 1.4520 at 20°. Prepd by adding to CHCO₂C₂H₅ the sodium salt of nitromethane in methanol, under 5°.


**Ethyl-3,3-Dinitrolactate, CH(NO₂)₂CHOHCO₂C₂H₅;**

mp 208.13, N₃.46%, OB to CO₂-53.4% liq, nD¹ 1.4573 at 25°. Prepd by adding the half (ethyl)acetate of ethylglycoloxalate to KCH(NO₂)₂ and acidifying the intermediate potassium salt (mp 144° dec).

Refs: 1) Beil, not found 2) L.W. Kissinger et al, JOC 22, 1658-62 (1957) & CA 52, 8963 (1958)

**Ethyl Malonate or Diethyl Malonate, CH₃(CO₂C₂H₅)₂;**

mp 160.17, col liq with sweet ether odor, sp gr 1.055 at 25-25°, fr p -50 to 51.5°; bp 198-199.3°; practically insol in w; sol in alc, eth, chl & benz. Can be prepd by passing HCl into cyanoëctric acid dissolved in abs ethanol, with subsequent distillation. Used as intermediate for barbiturates and certain pigments.


**Ethylmalonic Acid and Derivatives**

*Ethylmalonic Acid,* C₅H₉O₄CH(COOH)₂; mw 132.11; col prisms, mp 111.5°; bp-decomp at 160°, very sol in w, alc or eth. Can be obtd from α-bromo-butric acid heated with K mercuric cyanide, followed by KOH.

Refs: 1) Beil 2, 643, and (753) & (569) 2) J. Wislicenus, Ber 2, 721 (1869) 3) CondChemDict (1961), 473-R

**Ethylmalonic Acid Monoazide**

C₅H₉O₄(CH₂O₂H)CON₃, mw 157.13, N₂6.74%; yellow, sol in w, eth, chl & alc; expl weakly on heating. Prepd by diazotization of the K salt of the monohydrazide.

Refs: 1) Beil 2, (570) 2) T. Curtius & W. Sieber, Ber 55, 1555 (1922) & CA 16, 3883 (1922)

1.-Ethyl-iso-melamine,

(N(C₃H₇)C(=NH)NH)(=NH)NH₃ (=NH); mw 154.175, N₅4.50%. Prepd by mixing HCl, C₅H₄NH and HCl, add monopotassium dicyanoguananide, and heating. Isolated as the hydrochloride salt, dec 312°.

Refs: 1) Beil, not found 2) D.W. Kaiser & D.E. Nagy, USP 2481758 (1949) & CA 49, 9296 (1950)

**Ethylmercaptan, Ethylsulphhydrate or Ethanthiol, C₅H₁₁SH;**

mw 62.13; col, volatile, very unpleasantly garlic smelling liquid; flammable, sp gr 0.899 at 20/4°, fr p -121°, bp 36-37°, nD¹ 1.4305 at 20°, fl p < 0°; sol in w; sol in alc, eth, petr naphtha & alkalis. Can be prepd by saturating KOH soln with H₂S, mixing with Ca ethylsulphate soln and distilling on a water bath (Ref 4). See also Refs 1&2. Was proposed for use in self-igniting rocker fuels (Ref 3).

This compd was listed in Vol 1 of Encycl,
Acrylic, Dynel and Vinyon N are also acrylate resins or acrylics since they are copolymers of acrylonitrile. Acrylic rubbers, including acrylonitrile rubber are also of this general class.

Ethyl Methacrylate or Ethyl Methylacrylate,

H₂C₃(CH₃)COOC₂H₅; mw 114.14 col liq, sp gr 0.913 at 15.6°C, bp 118-119°C, f l p (open cup) 95°F; insol in w; sol in alc or eth; readily polymerizes. Can be prep by reaction of methacrylic acid with ethanol.

Was used in prep of acrylate resins and of other copolymers and polymers. Acrylate resins are thermoplastic polymers or polymers of acrylic and methacrylic acid, esters of these acids or acrylonitrile. Acrylic acid & acrylonitrile and their derivatives are described in Vol 1 of Encycl, pp A96-R & A97.

Ethyl Methacrylate is α-methylacrylic acid,

CH₂C(CH₃)COOH described in CondChem Dict (1961), p 723-R.

These monomers polymerize readily in presence of light, heat or catalysts (such as benzoyl peroxide) and must always be stored or shipped with inhibitor present to avoid spontaneous and explosive polymerization. The cyclic and acrylic esters range from soft, sticky, semifluid materials to hard solids. The polymeracrylates are harder than corresponding polyacrylates and the methyl esters form harder resins than the ethyl or butyl esters. Polyethylmethylacrylate, examples of which are Lucite and Plexiglas, is outstanding for its clarity and transparency. An almost unique property is that of carrying light around corners and reflecting it out the edges of a piece of cast polymer. Additional characteristics of acrylate resins are: low water absorption, low sp gr, good shock resistance. They are compatible with many plasticizers and are soluble in aliphatic hydrocarbons, chlorinated hydrocarbons, esters and ketones.

Their uses are very extensive, such as: aircraft canopies & windows, instrument dials, safety glass, contact lenses, lighting fixtures, refrigeration parts, dentures, paints & finishes, adhesives etc. The synthetic fibers Orlon.

Ethylmethane Sulfonamide and Derivatives

Ethylmethane Sulfonamide,

H₄C₅SO₂NH·CH₂₃, mw 123.175, col liq, sp gr 1.191 at 24°C, bp 105.5°C (0.3 mm Hg), nD₂ 1.4900 at 25°C, sol in w. Prepd by mixing at 0°C 1 mole of C₂H₅NH₃Cl, 1 mole of CH₃SO₂Cl, & 2 moles of NaOH in w.

These monomers polymerize readily in presence of light, heat or catalysts (such as benzoyl peroxide) and must always be stored or shipped with inhibitor present to avoid spontaneous and explosive polymerization. The cyclic and acrylic esters range from soft, sticky, semifluid materials to hard solids. The polymeracrylates are harder than corresponding polyacrylates and the methyl esters form harder resins than the ethyl or butyl esters. Polyethylmethylacrylate, examples of which are Lucite and Plexiglas, is outstanding for its clarity and transparency. An almost unique property is that of carrying light around corners and reflecting it out the edges of a piece of cast polymer. Additional characteristics of acrylate resins are: low water absorption, low sp gr, good shock resistance. They are compatible with many plasticizers and are soluble in aliphatic hydrocarbons, chlorinated hydrocarbons, esters and ketones.

Their uses are very extensive, such as: aircraft canopies & windows, instrument dials, safety glass, contact lenses, lighting fixtures, refrigeration parts, dentures, paints & finishes, adhesives etc. The synthetic fibers Orlon.

Acrylon, Dynel and Vinyon N are also acrylate resins or acrylics since they are copolymers of acrylonitrile. Acrylic rubbers, including acrylonitrile rubber are also of this general class.

Trinitroethylmethanesulfonamide,

(O₂N)₃C·CH₂₃(NO₂)·SO₂·CH₃; mw 303.17, N18.48%(NO₂) OB to CO₂2.6%, crystals, sp gr 1.82, mp 52°C. Prepd by the nitration of n-Trinitroethylmethane sulfonamide. Its sensitivity to impact is comparable to Pentolite.
Ethylmethyl Aniline and Derivatives

N-Ethyl-N-Methyl Aniline, C₆H₅N(CH₃)CH₂; mw 135.21, N10.36%; liq, sp gr 0.9193 at 55°/4, bp 203-5°, sol in alc & eth. Prepd from ethylmethylamine & CH₃I. Forms a picrate, green-yellow prisms, mp 134-5°.
Refs: 1) Beil 12, 162,(156) & [91] 2) A.W. Hofmann, Ann 74, 152 (1850)

2-Nitro-N-Ethyl-N-Methyl Aniline, O₂NCH₂N(CH₃)CH₂; mw 180.21, N15.55%; Prepd by heating diethylsulfate with 2-nitro-N,N-dimethylaminol, and isolation as the picrate, mp 126-7°.
Refs: 1) Beil, not found 2) H.A. Fahim & M. Galaby, JCS 1950, 3529-32 & CA 45, 7037 (1951)

4-Nitro-N-Ethyl-N-Methyl Aniline, O₂NCH₂N(CH₃)CH₂; mw 180.21, N15.55%; crysts, mp 88°. Prepd by heating diethylsulfate with 2-nitro-N,N-dimethylaminol to give the quaternary anilinium ethyl sulfone salt which was then heated to give the 4-Nitro-
N-Ethyl-N-Methyl compound
Refs: 1) Beil, not found 2) H.A. Fahim & M. Galaby, JCS 1950, 3529-32 & CA 45, 7037 (1951)

N-(2-Nitroethyl)-N-Methyl Aniline, C₆H₅N(CH₃)CH₂O₂N(CH₃); mw 180.21, N15.55%; liq, bp 110°(0.2mmHg), 112°(0.05mmHg) mp 45°, nD₁ 1.5635 at 20°. Prepd from N-methyl aniline and CH₂=CHNO₂. The HCl salt, mp 82°, is stable

2,4-Dinitro-N-Ethyl-N-Methyl Aniline
(O₂N)₂C₆H₄N(CH₃)CH₂; mw 225.21, N18.66%; crysts, sp gr 1.429 at 10° mp 59°(55°). Prepd from 2,4-dinitrochloro-
benzene and ethylmethylaniline

Ethylmethylbenzenes and Derivatives

4-Ethyl-1-Methyl-benzene, CH₃C₆H₄C₂H₅; mw 120.20, mp 162°, bp 207-4°, nD₁ 1.4929 at 24.4°. Prepd from 4-
bromoroluene, ethyl bromide and sodium in eth

3-Ethyl-1-methyl-benzene, CH₃C₆H₄C₂H₅; mw 120.20, liq, sp gr 0.869 at 20°, bp 150°, nD₁ 1.4965 at 19.8°. Prepd from 3-bromoroluene, ethyl bromide and sodium in eth
Refs: 1) Beil 5, 396,(192) & [309] 2) E. Wroblewski, Ann 192, 198(1878)

2-Nitro-4-ethyl-1-methyl-benzene, CH₃C₆H₄C₂H₅(NO₂); mw 156.20, N8.48%; liq, bp 247-9°, 73-6°(1 mm Hg). Prepd by nitration of the parent compound

3-Nitro-4-ethyl-1-methyl-benzene, CH₃C₆H₄C₂H₅(NO₂); mw 165.20, N8.48%; liq, bp 115-20°(10 mm Hg), 69-73° (1 mm Hg). Prepd by hydrazine reduction of 3-nitro-4-ethylbenzaldehyde (bp 155° at 10 mm), from 4-ethylbenzaldehyde and KNO₂ in H₂SO₄ at 0°

2-Nitro-3-ethyl-1-methyl-benzene, CH₃C₆H₄C₂H₅(NO₂); mw 165.20, N8.48%; liq, bp 72-6°(1 mm Hg). Prepd from the parent and a mixture of concd sulfuric and 70% nitric acids at 0-5°
Refs: 1) Beil, not found 2) M. Dolinsky et al, AssocOffic-AgrChem J 42, 709-20 (1959) & CA 54, 4268 (1960)(Also infrared spectrum)
4-Nitro-3-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 165.20, N8.48%; liq,
bp 253-63°, 70-1°(0.7 mm Hg). Prepd from
4-ethyl-2-methyl-acetanilide by HNO₃ / H₂SO₄ -
mp 143°, hydrolysis to the aniline - mp 74°,
and diazotization/removal of the amine group
Refs: 1)Beil, not found 2)G.T.Morgan &
A.E.J.Pettee, JCS 1934, 418-22 & CA 28,
4396-7 (1934) 3)M. Dolinsky et al, Assoc-
Office Agr Chem J 42, 709-20 (1959) & CA 54,
4268 (1960) (Prepn & infrared spectrum)

5-Nitro-3-ethyl-1-methyl-benzene
CH₃C₆H₅C₂H₅(NO₂)₂; mp 165.20, N8.48%;
liq, bp 263-4°. Prepd from 4-ethyl-2-methyl-
acetanilide by HNO₃ / HAc in the cold,
mp 142°, hydrolysis to the aniline - mp 64°,
and diazotization/removal of the amine group
Refs: 1)Beil, not found 2)G.T.Morgan &
A.E.J.Pettee, JCS 1934, 418-22 & CA 28,
4396-7 (1934)

6-Nitro-3-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 165.20, N8.48%;
liq, bp 245°, 70-1°(0.5 mm Hg). Prepd from
the parent with HNO₃ / HAc in the cold
Refs: 1)Beil 5, [310] 2)A.Mailhe, CR173,
160-2 (1921) & CA 15, 3985 (1921) 3)
M.Dolinsky et al, Assoc Office Agr Chem J 42,
709-20 (1959) & CA 54, 4268 (1960) (Prepn
& infrared spectrum)

2,3-Dinitro-4-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 210.20, N13.33%;
plates (alc), mp 51-2°, sol in boiling alc.
Prepd from the parent with cold fuming nitric
acids
Refs: 1)Beil 5, 399 2)P.Jannasch & A.
Dieckmann, Ber 7, 1514 (1874) 3)O.L.
Brady & J.N.E.Day, JCS 1934, 114-2 & CA 28,
1993 (1934)

2,4-Dinitro-4-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 210.20, N13.33%;
mp 62.5°. Prepd from the 2,3,6-trinitro deriv-
ative (see below) by reaction with ammonia
to give the 3-amino, mp 143°, which was re-
acted in alc with HNO₃ to remove the amino
group
Refs: 1)Beil, not found 2)O.L.Brady &
(1934) 3)I.L.Rinke, RecTravChim 64, 205-13 (1945) & CA 40, 4034 (1946)

3,5-Dinitro-4-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 210.20, N13.33%;
yel crys, mp 48.5°. Prepd from 5-ethyl-2-
methyl-acetanilide by nitratin at -10°
mp 177-8°, hydrolysis to the aniline - mp 186°,
followed by diazotization/removal of the
amine group
Refs: 1)Beil, not found 2)I.L.Rinke,
RecTravChim 64, 205-13 (1945) & CA 40,
4034, (1946)

Dinitro-3-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 210.20, N13.33%;
oil, steam distils. Prepd from the parent
compd and cold fuming nitric acid. Not
further identified
Refs: 1)Beil 5, 397 2)E.Barlow & A.W.Sel-
lards, JACS 27, 372 (1905)

2,3,5-Trimino-4-ethyl-1-methyl-benzene
CH₃C₆H₅C₂H₅(NO₂)₂; mp 255.20, N16.47%;
mp 82°. Prepd from the 3,5-dinitro compound
and HNO₃ / H₂SO₄ / SO₃
Refs: 1)Beil, not found 2)I.L.Rinke, RecTravChim 64, 205-13 (1945) & CA 40, 4034
(1946)

2,3,6-Trimino-4-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 255.20, N16.47%;
col prisms (alc), mp 93°, sl sol in cold alc.
Prepd from the parent compd and HNO₃ / H₂SO₄
by warming
Refs: 1)Beil 5, 399 2)E.Glinzler & R.Fit-
tig, Ann 136, 314 (1865) 3)O.L.Brady &
J.N.E.Day, JCS 1934, 114-21 & CA 28,
1993 (1934) (Prepn) 4)I.L.Rinke, RecTravChim 64, 205-13 (1945) & CA 40, 4034 (1946)
(Prepn)

2,4,6-Trimino-3-ethyl-1-methyl-benzene,
CH₃C₆H₅C₂H₅(NO₂)₂; mp 255.20, N16.47%;
plates (alc) mp 86° 90°. Prepd from the
dinitro compd by fuming nitric/concined
sulfuric acids
Refs: 1)Beil 5, 389 & [310] 2)E.Barlow
& A.W.Sellards, JACS 27, 372 (1905) 3)A.Mailhe, CR 173, 160-2 (1921) & CA 15,
3985 (1921)
Ethylmethylbiimidazole and Derivatives, 4-Ethyl-4'-methyl-2,2'-biimidazole, 
\[ \text{NH-CH=CH(CH}_3)_2\text{N} = \text{C-NC(C}_2\text{H}_5) = \text{CHNH} \] 
MW 176.223. This compound is not mentioned in the open literature.
Refs: 1) Beil, not found 2) CA, not found

4-Ethyl-4'-methyl-1',5,5'-tetrinitro-2,2'-biimidazole, 
\[ \text{N(NO}_2)_2\text{C(NO}_2)_2\text{C}(\text{CH}_3)_2\text{N} = \text{C-NC(C}_2\text{H}_5) = \text{C(NO}_2)_2\text{N(NO}_2)_2\] 
MW 356.21, N15.73% (NO₃), OB to CO₂ 62.9%, mp 226°C (dec). Prepd by adding diethyldisulfate to the sodium salt of the tetrinitrobatimidazole to make the 4-ethyl compound (mp 256°C as the dihydrate), and then reacting with diazomethane to give 4'-methyl
Refs: 1) Beil, not found 2) K. Lehmann, Ann 507, 213-215 (1933) & CA 28, 767 (1934)

Ethylmethylcarbamate. See Ethylmethylurethane.

Ethylmethyl Carbimol. See Butan-1-ol under Butanol in Vol 2, p B372-R

N-Ethyl-methylenediamine. See Diaminopropane in Vol 5 of Encyclopedia, p D1142

Ethylmethyl Ether or Methylmethyl Ether, 
\[ \text{C}_2\text{H}_5\text{O-CH}_3 \] 
MW 60.09; col, volatile, flammable; liq; sp gr 0.697 at 21.1/4°C (Lange), 0.725 at 0/0°C, bp 76°C (Lange), 10.8°C (Ref 3), nD 1.3420 at 4°C; sol in w, acet, chlf, alc & eth. Prepd by heating to 150°C isopropyl iodide, triethylamine and ethanol
Refs: 1) Beil 1, 362 & (381) 2) E. Reuber, Jahrb Ferscht Chem 1881, 409

2-Nitroethyl Isopropyl Ether, 
\[ \text{CH}_3\text{CH} (\text{CH}_3) \text{OCH}_2\text{CH}_3\text{NO}_2 \] 
MW 135.15, nD 10.52%; liq, bp 43°C (0.5 mm Hg). Prepd by refluxing 1,2-dinitroethane with isopropyl alcohol
Refs: 1) Beil, not found 2) A. Lamb, et al, JCS 1947, 1474-7 & CA 42, 4907 (1948)

Ethyl-a-Nitromethyllethyl Ether, 
\[ \text{CH}_3\text{CH} (\text{CH}_3) \text{NO}_2 \text{OC}_2\text{H}_5 \] 
MW 135.15, N 10.52%; liq, sp gr 1.0314 at 20°C, bp 69°C (11 mm Hg), 42°C (1 mm Hg), nD 1.4200 at 20°C. Prepd by refluxing with 1-nitro-2-propanol

Ethyl-a-Methyltrinitroethyl Ether, 
\[ \text{C(NO}_2)_2\text{OCH}_2\text{H}_5 \] 
MW 225.15, N18.66%, OB to CO₂ 53.3%; liq, sp gr 1.3145 at 20/20°C, bp 71-3°C (3 mm Hg), 63-4°C (0.6 mm Hg), nD 1.4386 at 20°C. Prepd by reacting nitroform with ethyl vinyl ether in dioxane

Ethylmethylisoxazole and Derivatives

3-Ethyl-5-methyl-isoxazole, 
\[ \text{N}=\text{C(} \text{C}_2\text{H}_5 \text{)} \text{CH=CH} (\text{CH}_3) \text{O} \] 
MW 111.14, N12.60%; liq, bp 90°C (73 mm Hg), nD 1.4450 at 20°C. Prepd by reacting at 0°C propionyl magnesium bromide with propionohydroxamic chloride in eth. Other preps are given in the same Ref, but the 5-ethyl-3-methyl isomer was also formed and it was not possible to separate the two
Refs: 1) Beil, not found 2) H. Feuer & S. Markovesky, JOC 29 (4), 938 (1964) & CA 60, 13234 (1964)

Note: See under Ethylene in this Vol for a trinitro derivative of this isoxazole.
Ethylmethyl Ketone or Methyl ethyl Ketone.
See Butanone in Vol 2 of Encycl, p B374-R

Ethylmethyl Ketone Peroxide (Dimolekulares Methyläthylketonsuperoxyd, in Ger),
\( \text{C}_6\text{H}_{10}\text{OOC(\text{C}_2\text{H}_5\text{C}_6\text{H}_5}\text{O})_2 \text{H}_2 \text{O} \); mw 176.215 liq, sp gr 1.042 at 15°, insol in w, sol in alc, eth & benz. Prep'd from ethylmethylketone and 2½% \( \text{H}_2\text{O}_2 \) in the presence of \( \text{H}_2\text{SO}_4 \). Distillable only in the presence of \( \text{w} \), 48°, (80 mm Hg), 56° (130 mm Hg); expn on heating over 100° or by stirring with concd \( \text{H}_2\text{SO}_4 \).

Sold commercially as a 30-60% soln of a mixture of compounds corresponding to breaking one or both 0-0-0-linkages (hydroperoxides, hydroxy-hydroperoxides, etc.); used to initiate polyest her resin polymerization.

\textit{Lupersol DDM} is the trade name of Wallace & Tieman, Inc, Lucindol Div, 1740 Military Rd, Buffalo, NY, 14205


Ethylmethylketone-semicarbazone and Derivatives

\( \text{C}_6\text{H}_8\text{C(N)H}_2\text{O} \text{OOC(\text{C}_2\text{H}_5\text{)}(\text{C}_6\text{H}_5\text{)}\text{O})_2 \text{H}_2 \text{O} \); mw 170.17, N49.38%; ndls (benz) mp 101°, sol in hot w.

Prep'd from ethyl azidomethylketone and semicarbazide hydrochloride in the presence of sodium acetate and \( \text{H}_2\text{O} \).

Refs: 1)Beil 3, 102 2)M.O. Forster & H.E. Fierz, JCS 93, 676 (1908)

Ethylmethylketone-semicarbazone Azide or Ethyl Azidomethylketone-semicarbazone.

\( \text{C}_6\text{H}_8\text{C(N)H}_2\text{N} \text{NHCONH}_2 \); mw 170.17, N49.38%; ndls (benz) mp 101°, sol in hot w.

Prep'd from ethyl azidomethylketone and semicarbazide hydrochloride in the presence of sodium acetate and \( \text{water} \).

Refs: 1)Beil 3, 102 2)M.O. Forster & H.E. Fierz, JCS 93, 677 (1908)

Ethylmethyl Nitrone and Derivatives. See under 3-Aza-4-oxa-hexene-2 in Vol 1 of Encycl, p 517-L for the parent and a tri-nitro derivative, the latter originally thought possibly to be a nitrone, but later proved otherwise.

Ethylmethyl Peroxide, \( \text{C}_6\text{H}_8\text{O}_2\text{OCH}_3 \);
mw 76.09; col liq; sp gr 0.8337 at 17/4°, fr p -68 to -69.5°, bp 40° at 740mm, Np1.3590 at 17° diff sol in w; easily sol in alc, eth, hexane and many other org solvents. Can be prep'd by treating ethylhydroperoxide (qv) with dimethyl sulfate in 50% KOH soln in atmosphere of nitrogen, first in the cold then at 70°.

It expn on heating or impact.

Refs: 1)Beil 1, [325] 2)A.Riche, Ber 62, 224 (1929) 3)Tobolsky & Mesrobian (1954), 164

Ethylmethylphenyl Ether and Derivatives

\( \text{Ethyl-3-methylphenyl Ether} \text{C}_6\text{H}_8(\text{CH}_3)\text{OC}_2\text{H}_5 \);
mw 136.18, liq, sp gr 0.9650 at 0/0°, bp 192°.

Prep'd from m-cresol, ethyl iodide and KOH.

Refs: 1)Beil 6, 376, (186) & [352] 2)A.Oppenheim & S.Pfaff, Ber 8, 887 (1875)

Ethyl-(4-nitro-3-methylphenyl)-ether,
\( \text{C}_6\text{H}_8(\text{CH}_3)(\text{NO}_2)\text{OC}_2\text{H}_5 \); mw 181.18, N7.73%; prisms (pet eth), mp 55°.

Prep'd from ethyl iodide in eth and the silver salt of 6-nitro m-cresol.

Refs: 1)Beil 6, 385 2)W.Staedel & A.Kolb, Ann 259, 224 (1890)

Ethyl-(6-nitro-3-methylphenyl)-ether,
\( \text{C}_6\text{H}_8(\text{CH}_3)(\text{NO}_2)\text{OC}_2\text{H}_5 \); mw 181.18, N7.73%; ndls (alc), mp 54°.

Prep'd by adding ethyl m-tolyl ether in HAC to sp gr 1.505 HNO3 in the cold.

Refs: 1)Beil 6, 386 2)W.Staedel, Ann 217, 161 (1883)
Ethyl-(4,6-dinitro-3-methyl phenyl)-ether, 
C₆H₅(CH₃)(NO₂)₃OC₂H₅; mw 226.18, N 12.39%; 
wh nds (dil alc), mp 97°C, sol in eth, chl & 
benz. Prepd by reacting the 4-nitro-3-methyl-
edoxy-benzene with fuming nitric acid
Refs: 1) Beil 6, 367, (194) 2) W. Staedel 
& A. Kolb, Ann 259, 219 (1890)

Ethyl-(2,4,6-trinitro-3-methylphenyl)-ether, 
C₆H₃(CH₃)(NO₂)₃OC₂H₅; mw 271.18, N 15.49%; 
wh plates (alc), mp 75°C, sol in alc, eth, benz, 
chl & acet. Prepd by reacting ethyl iodide 
in alc with the silver salt of 2,4,6-Trinitro-
cresol
Refs: 1) Beil 6, 388 & (195) 2) E. Noeltling 
& V. Salis, Ber 15, 1864 (1881) 3) M. Gua, 
Gazz 49, 11, 158-66 (1919) & CA 14, 1532 (1929) (Prepd)

5-Ethyl-2-methyl Pyridine, 2-Methyl-5-ethyl-
Pyridine (MEP) or Aldehydine (2,5), 
(CH₃)C₆H₄N(C₂H₅); mw 121.18; liquid, sp gr 
0.921 at 20/20°C, fr p 70.3°, bp 178.3°C, nD 
1.4970 at 20°C, fl p (Cleveland open cup) 165°F; 
only insol in w; sl sol in aq alc, sol in alc, 
eth & H₂SO₄. Can be prep by treating para-
aldehydine with ammonia under high pressure 
and in presence of Amm acetate as a catalyst. 
Used as intermediate for gemicides and tex-
tile finishes; as a corrosion inhibitor for chlor-
inated solvents (Ref3)
Note: It has been reported that when a mix-
ture of EthMe-pyridine with 70% nitric acid 
total vol 6.2 ml) was heated in a 1-liter 
autoclave a sudden rise of pressure, followed 
by a violent explosion took place. It is 
advised that reaction vessels be only 1/5th 
full and provided with adequate cooling and 
fast venting.
Refs: 1) Beil 20, 248, (86) & [162] 2) 
G. Krämer, Ber 3, 262 (1870) 3) Cond Chem Dict 
(1961), 739-R & 740-L (2-Methyl-5-ethyl-
pyridine) (1971), p 758-R (5-Ethyl-2-methyl 
Pyridine) 4) Sax (1968), p 574-L

7-Ethyl-2-methyl-4-undecanol, 1-Tetradecanol 
or Myristyl Alcohol, 
C₄H₉(CH₂CH₃)(CH₂)sOC₂H₅; mw 214.40, liq or wh solid, sp gr 0.8355 at 
20/20°C, fr p 38°, bp 264°C, fl p 285°C; insol in w. Can be prep by slow addition of a mixture 
of 4-methyl-2-pentanol, Zn dust and zinc oxide to 
sodium -2-ethyl-1-hexanoate at 175°C. Used 
as an intermediate for synthetic lubricants, 
defoamers and surfactants (Ref3)
Refs: 1) Beil, not found 2) C. A. Carter, USP 
2457866 (1949) & CA 43, 3438 (1949) 3) Cond-
Chem Dict (1961), 474-R; (1971), p 372-L (7-
Ethyl-2-methyl-4-undecanol), p 600-L (Myrist-
yl Alcohol) & p 855-R (Tetradecanol) 4) 
Sax, 8th edit (1968), p 1143-L (Tetradecanol)

Ethynitramine. See Nitramine noethane or N-
Nitroethylanime in Vol 1 of Encycl, p A199-R, 
under AMINOETHANE AND DERIVATIVES

1-(N-Ethyl)nitramino-2-ethanol Nitrate or 
ETENA. See under Ethylaminoethanol in this Vol

Ethyl Nitrate. See Ethane Nitrate in this Vol

Ethyl Nitrate, Azide. See Ethane Azidonit-
rate or Ethylazido-Nitrate in this Vol

Ethyl Nitrite. See Ethane Nitrite in this Vol

Ethyl Nitro-Nitroso-Dinitro-etc Compounds 
are described under Ethane in this Vol

2-Ethyl-1,2-nitro-1,3-propanediol Dinitrate. 
See 1.1-Di(methylol)-1-nitropropane Dinitrate 
in Vol 5 of Encycl, p D1359-L

Ethynitrolic Acid, CH₃C(=NOH).NO₂; 
mw 104.07, N26.91%, OB to CO₂ 46.2%; 
crysts, mp 88°C (decomp), sol in w, alc or 
eth. Can be prep by reacting HNO₃ with 
the sodium salt of nitroethane
Refs: 1) Beil 2, 189, (86) & [185] 2) 
V. Meyer, Ann 175, 98 (1875)

Ethynitrosalic Acid, CH₃C(=NOH).NO₂; 
mw 88.07, N 31.79%. Prep by reducing 
ethyl nitric acid with NaHg. Known only 
as its salts, as it can not be isolated from
Ethanolamine, Dinitro. See under Amino-ethanol in Vol 1, p A201-R

Ethyl Oleate, C_{17}H_{35}.COOC_{2}H_{5}; mw 310.50, \text{It} yel oily liq, sp gr 0.869 at 20/4°C, fr p \text{<15°C} (Lange), approx -5°C (Ref 3), nD 1.45189 at 20°C, fl p 347.5°F (175.3°C); insol in w; sol in alc & eth. Can be prep'd from oleic acid, alc and concd H₂SO₄. Used as solvent, lubricant, plasticizer or water-resistant agent (Ref 3)


Ethyl Oxalate or Diethyl Oxalate, \text{<COOC}_{2}H_{5}>_{2}; mw 146.14, col, unstable aromatic liquid; combustible but not flammable; sp gr 1.079 at 20/4°C (Lange), 1.09 at 20/20°C (Ref 3), fr p \text{-40.6°C}, bp 185-186°C fl p 168°F; v sl sol in w with gradual decomp; miscible with alc, eth, eth acetate and other common org solvents. Can be prep'd by standard esterification procedure using ethanol & oxalic acid. The final purification, however calls for specific technique and equipment (Ref 3). Used as solvent for cellulose esters & ethers and for synthetic resins; also for radio tube cathode fixing lacquers, pharmaceuticals, etc


Ethyl Oxamate or Oxamethane, H₂N.CO.COOC₂H₅; mw 117.10, N11.96%; rhom plates (hot alc), mp 114-115°C sol in w & eth; v sl sol in alc. Can be prep'd from diethylene and ammonia gas


Ethyl Oxide. Same as Ether (qv)

Ethyl Palmitate, C₁₄H₂₇.COOC₂H₅; mw 284.47; col ndls, sp gr 0.858 at 25/4°C, mp 24-25°C, bp 191°C at 10 mm, nD 1.4278 at 50°C insol in w, sol in alc & eth. Can be prep'd by heating palmitic acid with ethanol in presence of HCl (Refs 1&2)

It was proposed by the duPont Co(Ref 3) to prepare flashless smokeless propellants from NC & DNT, in which is incorporated ethyl palmitate or other esters of organic acids insol in water but forming a gelatinous mass with NC & DNT at about 80°C

Ethylpentanoate and Derivatives

*Ethylpentanoate*,
\( \text{H}_3\text{C.CH}_2\text{OOC.CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \); mw 130.19, liq, sp gr 0.8765 at 20\(^\circ\), bp 145.5\(^\circ\), n\(_D^2\) 1.4044 at 15\(^\circ\). Prepd by reducing ethyl levulinate with zinc amalgam in alcoholic HCl.

*Refs*: 1) Beil 2, 301 (130) & [266] 2) W. Steinkopf & A. Wolfram, Ann 430, 142 (1923)

*Ethyl-2-azidopentanoate*,
\( \text{H}_3\text{C.CH}_2\text{OOC.CH(N}_3\text{).CH}_2\text{CH}_2\text{CH}_3 \); mw 171.20, N24.55%, liq, bp 65-70\(^\circ\) (2.8 mm Hg). Prepd by reacting NaN\(_3\) with ethyl-2-bromopentanoate in aq alc.

*Refs*: 1) Beil, not found 2) R. M. Moriarty & M. Rayman, Tetr. 21 (10), 2877-91 (1965) & CA 64, 3312 (1966)

*Ethyl-5-azidopentanoate*,
\( \text{H}_3\text{C.CH}_2\text{OOC.CH}_2\text{CH}_2\text{CH}_2\text{.CH}_2\text{N}_3 \); mw 171.20, N24.55%, liq, bp 105-107\(^\circ\) (13 mm Hg). Prepd by reacting NaN\(_3\) with ethyl-5-bromopentanoate.


*Ethyl-2-nitropentanoate*,
\( \text{H}_3\text{C.CH}_2\text{OOC.CH(NO}_3\text{).CH}_2\text{CH}_2\text{CH}_3 \); mw 175.19, N8.00%, liq, sp gr 1.0713 at 20\(^\circ\), bp 51\(^\circ\) (0.1 mm Hg) 90\(^\circ\) (8 mm Hg), n\(_D^2\) 1.4270 at 20\(^\circ\), sol in alc, eth, benz. Prepd from the 2-nitroso compd by oxidizing with H\(_2\)O\(_2\) in H\(_2\)SO\(_4\).


*Ethyl-3-nitropentanoate*,
\( \text{H}_3\text{C.CH}_2\text{OOC.CH}_2\text{CH(NO}_3\text{).CH}_2\text{CH}_3 \); mw 175.19, N8.00%, liq, bp 105-107\(^\circ\) (15 mm), contains 12% 3-bromo compd). Prepd from the reaction of NaN\(_3\) with the 3-bromo compd in the presence of chloroglucinol in dimethylformamide at 60\(^\circ\).


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**Ethylpentane and Derivatives**

3-Ethylpentane or Triethylmethane,
\( \text{H}_3\text{C.CH}_2\text{CH.CH}_2\text{CH}_3 \); mw 101.21, col liq, C\(_2\)H\(_5\)

**sp gr** 0.69181 at 20\(^\circ\), fr p -118.6\(^\circ\), bp 93.5\(^\circ\), n\(_D^2\) 1.3934 at 20\(^\circ\), insol in w; sol in alc. Can be prepd from ethyl orthoformal, ethyl zinc, and sodium. Used in organic synthesis


3-Nitro-3-ethylpentane,
\( \text{H}_3\text{C.CH}_2\text{C(NO}_3\text{).CH}_2\text{CH}_3 \); mw 145.20, C\(_2\)H\(_5\)

N9.55%, liq, sp gr at 0/0 0.9549, bp 185-90\(^\circ\). Prepd from trichloronitrime edane and diethyl zinc.


2,2-Dinitro-3-ethylpentane,
\( \text{H}_3\text{C}(\text{NO}_3\text{).CH}_2\text{CH}_2\text{CH}_3 \)

C\(_2\)H\(_5\)

mw 190.20, N14.73%, bm yel oil, bp 211-196. Prepd by oxidation with Cr\(_2\)O\(_7\)/HAc of asymetrical diethyl(propylpseudonitro)

*Refs*: 1) Beil 1, 157 2) G. Born, Ber 29, 100 (1896)

2,2,3-Trinitro-3-ethylpentane,
\( \text{H}_3\text{C.C(NO}_3\text{).CH}_2\text{CH}_2\text{CH}_3 \)

C\(_2\)H\(_5\)

mw 235.20, N17.87%, crys, mp 85.5-87.5\(^\circ\). Prepd from the parent and ethyl nitrate in HCl to give 2-nitroso-3-chloro-3-ethylpentane, which was treated with conc HNO\(_3\). The compd is an expl comparable in sensitivity with TNT but only 82% as powerful by Ballistic Mortor

*Refs*: 2, 3


3) A. H. Blatt, "Compilation of Data on Organic Explosives," OSRD Rept 2014 (1944)
Ethyl-4-nitropentanoate,
\[ \text{H}_2\text{C} = \text{CH}_2 \cdot \text{OOC.CH}_2\text{CH} = \text{CH(NO}_2)_2 \cdot \text{CH}_3; \]
mw 175.19, N8.00%; liq, sp gr 1.0955 at
20/4\(^\circ\), bp 68-71\(^\circ\) (1 mm Hg, Ref 4), 94-5\(^\circ\)
(1-2 mm, Ref 2,3), n\(_D^20\) 1.4315 at 20\(^\circ\). Prepd
by reacting nitroethane with ethyl acrylate
in aq ammonia at -50\(^\circ\).
Refs: 1) Beil, not found 2) S. Wakamatsu
& K. Shimazu, JOC 27, 1609-11 (1962) & CA 57,
2050 (1962) 3) ibid, Japan P3419 (1964) &
CA 61, 2978 (1964) 4) W. Biernacki & T. Urbański,
(Infrared spectrum)

Ethyl 5-nitropentanoate,
\[ \text{H}_2\text{C} = \text{CH}_2 \cdot \text{OOC.CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NO}_2; \]
mw 175.19, N8.00%; liq, sp gr 1.075 at 25\(^\circ\),
bp 250-5\(^\circ\) (dec) 80\(^\circ\) (0.8 mm Hg), n\(_D^20\) 1.4344 at
25\(^\circ\). Prepd by heating NaNO\(_3\) in w at 85\(^\circ\)
with H\(_2\text{O} \cdot \text{CCH(Br)(CH)}_3 \cdot \text{CO}_2 \cdot \text{CH}_3.
Ref s: 1) Beil, not found 2) W. Treibs &
H. Reinheckel, Ber 87, 341-5 (1954) & CA 49,
4526 (1955)

Ethyl 4,4-dinitroptentanoate
\[ \text{H}_2\text{C} = \text{CH}_2 \cdot \text{OOC.CH}_2\text{CH}_2\text{CH}_2\text{CH}_3; \]
mw 220.18, N12.72%. Presumably prepd by
the addition of 1,1-dinitroethane to ethyl acrylate.
The only refs to this compound in the open literature
are a method of analysis for an expl con-
taining it (Ref 2), and its use in an extrud-
able expl (Ref 3).
Refs: 1) Beil, not found 2) W. Selig, US Army
Energy Comm UCRL-7873, 10-19 (1964) & CA
64, 9497 (1966) 3) M. Finger, et al, USP
3480490 (1969) & CA 72, 33910 (1970)

2,2,2-Trinitroethyl-4,4-dinitroptentanoate
(TNEDNP),
\[ (\text{O}_2\text{N})_8\cdot \text{C.CH}_2\cdot \text{OOC.CH}_2\text{CH}_2\cdot \text{C(NO}_2)_2\cdot \text{CH}_3; \]
mw 355.18, N19.72%, OB to CO\(_2\) 29.3%,
cryst, sp gr 1.60, mp 92.5-93\(^\circ\) ignition temp
297\(^\circ\). Was prepd at NAVORD lab by heating
the acid chloride of ethylpentanoate with
Trinitroethanol at 70\(^\circ\) in presence of anhy-
drous AlCl\(_3\). The acid chloride was prepd
by the addn of 1,1-Dinitroethane to methyl-
acrylate, followed by hydrolysis with aq HCl.
Its impact sensitivity is comparable to Comp A
and vacuum stability at 100\(^\circ\) 1.1 ml gas evol-
vured per Ig in 48 hours

Ethyl Perchlorate, C\(_2\)H\(_5\)ClO\(_4\); mw 128.52;
oily liq, bp 89-97\(^\circ\) (when heated covered
with water). Can be prepd by distilling Ba perchlo-
rate with Ba ethylsulfonate (Refs 1 & 2).

When dry, it is an extremely violent and
sensitive expl, exploding even on pouring from
one container into another (Refs 1 & 2). Its
power by Trauzl Test is 110SAPA (Ref 4).

Refs: 1) Beil 1, 324, [325] & [3134] 2)
H. E. Roscoe, Ann 124, 124 (1862) 3) J. Mey-
er & W. Spormann, Z Anorg Allg Chem 228,
341-51 (1936) & CA 30, 8057 (1936) 4)
Blatt, OSRD 2014 (1944)

Ethyli Peroxide. See Diethyl Peroxide in Vol 5
of Encycl p D1246-R

Ethyl Peroxide of Berthelot. See Ethyl Ozono-
ide or Tetaethyl Ozonide

Ethyl Peroxyacetate, C\(_3\)H\(_6\)CO.OO-C\(_2\)H\(_5\),
mw 104.11, oil. Believed to have been prepd
from acetic anhydride and a dilute soln of
ethyldihydroperoxide (Ref 2) but not further ex-
amined.

Refs: 1) Beil, not found 2) A. Baeyer &
V. Villiger, Ber 34, 746 (1901) 3) Tobolsky
& Mesoian (1954), 168

ETHYLPHENOLS AND DERIVATIVES

Ethylphenols, C\(_2\)H\(_5\).C\(_6\)H\(_4\).OH; mw 122.16.
Three isomers are known:

\(\alpha\)-Ethylphenol or Phloral, col liq, sp gr 1.018
at 25/25\(^\circ\), fr p -45, bp 202\(^\circ\) at 756 mm; v sl
sol in w; miscible with alc ether. Prepn is
in Ref 1

\(m\)-Ethylphenol, col liq, sp gr 1.001 at 25/25\(^\circ\),
fr p -40, bp 214\(^\circ\) at 752 mm; v sl sol in w;
miscible with alc & eth. Prepn is in Ref 2

\(p\)-Ethylphenol, col ndls, mp 46-47\(^\circ\), bp 219\(^\circ\),
v sl sol in w; v sol in alc or eth. Prepn is
in Ref 3
**Ethyl mono-nitrophenol.** Beil (Ref 1) lists only one compound of undetermined structure, with a base salt which explodes on heating. Prepd by nitration of ethylbenzene followed by treatment with nitric acid. Refs: 1) Beil 6, 475
2) W. Suida & S. Plohn, Monatsch 1, 181 (1880)

Other sources list, however:

- o-Ethyl 4-nitrophenol, C₆H₅CH₂OH(NO₂)₂, mw 167.16, ndl, mp 79-80°C sols usual organic solvs. Prepd by reacting 2-pentanonitrile with sodium nitromalonaldehyde in alcoholic base. Refs: 1) Beil, not found

- o-Ethyl 3-nitrophenol, C₆H₅CH₂OH(NO₂)₂, mw 167.16, solid, mp 76-7°C (pet eth). Prepd by treating o-ethyl 5-nitroaniline with nitrous acid at 0°C, Refs: 1) Beil, not found

- p-Ethyl 3-nitrophenol, C₆H₅CH₂OH(NO₂)₂, mw 167.16, liq bp 123-5°C (0.1 mm Hg), nD 1.5705 at 25°C. Prepd by treating with nitrous acid at 0°C p-ethyl 3-nitroaniline. Refs: 1) Beil, not found
2) F. Weszely et al, Monatsch 83, 24-30 (1952) & CA 46, 11151 (1952)
3) C. Hansch et al, JOC 21, 265-70 (1956) & CA 50, 16742 (1956) (Prepn and props)

**Ethyl dinitrophenols.** Beil (Ref 1) lists only one compound of undetermined structure, with an expb Pb salt. Prepd by nitrating o-ethylphenol with cold fuming HNO₃. Refs: 1) Beil 6, 471
2) W. Suida & S. Plohn, Monatsch 1, 181 (1880)

Other sources list, however:

- o-Ethyl 4,6-dinitrophenol, C₆H₅C₆H₄OH(NO₂)₂, mw 212.16, N13.20%, cryst. mp 37°C bp 120°C (0.01 mm Hg). Prepd by sulfonating o-ethylphenol followed by nitration starting at 0°C, ending with heating. Ref (4) describes an undetermined ethyl dinitrophenol derived from ethylbenzene which has the proper mp for this isomer, indicated to decompose at 270°C and having a Na salt exploding at 240°C and a Pb salt exploding at 210°C.

**Ref:**
1) Beil, not found
2) J. D. Pollard, USP 2048158 (1936) & CA 30, 6009 (1936)

**Ethyl 4,6-dinitrophenol,** C₆H₅C₆H₄OH(NO₂)₂, mw 212.16, N13.20%, solid, mp 85°C. Prepd by the mixed acid nitration of m-ethylphenol starting at 0°C and ending at 100°C. Refs: 1) Beil, not found

**p-Ethyl 2,6-dinitrophenol,** C₆H₄C₆H₄OH(NO₂)₂, mw 212.16, N13.20%, liq, bp 130°C (0.01 mm Hg). Prepd by nitration in HAc of p-ethylphenol. Refs: 1) Beil, not found

**m-Ethyl 2,4,6-trinitrophenol or 3-Ethyl Picric Acid,** C₆H₅C₆H₄OH(NO₂)₃, mw 257.16, N16.34%, cryst, mp 88°C. Prepd by addition of HNO₃ to 3-ethylphenol dissolved in H₂SO₄ at 10-20°C. Refs: 1) Beil, not found

**Ethylphenylacetic Acid and Derivatives, or**
**Ethylbenzylate and Derivatives**

**Ethylphenylacetic Acid,** C₆H₅CH₂CO₂H, mw 164.20, col liq, sp gr 1.033 at 20/4°C, bp 227°C, nD 1.499 at 18.5°C, insol in w; miscible with alc or eth. Can be prepd by simple esterification with HCl. Refs: 1) Beil 9, 434, (173) & (297)
2) B. Radziwizski, Ber 2, 208 (1869)

**Ethylphenyl Acetoacetic Acid or Ethylphenyl**
**Triazooacetate,** C₆H₄CH(N₂)CO₂C₂H₅, mw 205.21, liq, sp gr 1.434 at 20/20°C, bp 141°C (12 mm Hg). Prepd by esterification of the azido acid with alcoholic sulfuric acid. De-
composes vigorously with concd sulfuric acid
Refs: 1) Beil 9, (186)  2) A. Darapsky, J PrCh

2-Nitro Ethylphenylacetic Acid,
O₂NC₆H₄CH₂COOC₂H₅, mw 209.20, ndl (sllt)
mp 69 °C, sol in usual org solv. Prep by simple esterification with alcoholic HCl
Refs: 1) Beil 9, 455 & (182)  2) A. Reissert & J. Scherk, Ber 31, 395 (1898)

3-Nitro Ethylphenylacetic Acid,
O₂NC₆H₄CH₂COOC₂H₅, mw 209.20, oil, bp
85 °C (2 mm Hg). Prep from the acid chloride and alc. Ref (2) indicates the cmpd is un-
stable
J Biol Chem 68, 504 (1926)

4-Nitro Ethylphenylacetic Acid,
O₂NC₆H₄CH₂COOC₂H₅, mw 209.20, pl (pet
et), mp 65.5-66 °C, bp 196-7 °C (20 mm Hg).
Sol alc. Prep by simple esterification with alcohol HCl
Refs: 1) Beil 9, 456, (183) & [312]  2) T. Maxwell,
Ber 12, 1767 (1879)

Ethylphenyl nitroacetate,
C₆H₅CH(NO₂)COOC₂H₅ or C₆H₅C(:NO₂)H
COOC₂H₅, mw 209.20, oil, dec on distillation.
Prep as the Na salt by treating ethyl phenyl acetate with ethyl nitrate in eth in the
presence of Na. A Li salt crystallizes from alc as ndls with one molecule of alc of crys-
tallization; the alc evaporates at 150 °C and the remainder melts at 200 °C
Refs: 1) Beil 9, 457 & [313]  2) W. Wislicenus & A. Endres, Ber 35, 1755 (1902)

2,4-Dinitro Ethylphenylacetic Acid,
(O₂N)₂C₆H₄CH₂COOC₂H₅, mw 254.20, ndl
(w), mp 35 °C, sol in the usual org solv. Prep by esterification of the acid
Refs: 1) Beil 9, 459  2) S. Gabriel & R. Meyer,
Ber 14, 824 (1881)

Ethylphenyl Acetylene or 1-Phenyl-butyne-1,
C₆H₅C≡C₂H₅; mw 130.19, liquid, sp gr
0.923 at 21 °C, bp 201-203 °C, insol in w, sol in alc or ecb. Can be prep from sodium phenyl-
acetylide and ethyl iodide at 120-140 °C
Refs: 1) Beil, not found  2) L. J. Sargent,
JOC 19, 599-607 (1954) & CA 49, 5478 (1955)

2-Ethyl-4-Nitrophenylamine or
2-Ethyl-4-Nitroaniline, C₆H₅C₂H₅(NO₂)NH₂;
mw 166.18, N 16.86%; lfts or crspts, mp 87 °C.
Prep by nitrating with HNO₃/HAc at 50 °C
2-ethylacetanilide, followed by heating in acid to remove the CH₃CO-group
Refs: 1) Beil, not found  2) C. Hansch, JOC 20, 1026-9 (1955) & CA 50, 6368 (1956)

2-Ethyl-5-nitrophenylamine or
2-Ethyl-5-Nitroaniline, C₆H₅C₂H₅(NO₂)NH₂;
mw 166.18, N 16.86%; ndls, mp 62 °C.
Prep by reducing 2,4-dinitroethylbenzene with ammonium sulfide in alc, but not isolated (Ref 2)
until later (Ref 3)
Refs: 1) Beil 12, [584]  2) E. L. Cline & E. E.
Reid, JACS 49, 3152-4 (1927)  3) C. Hansch,
JOC 20, 1026-9 (1955) & CA 50, 6368 (1956)

2-Ethyl-6-nitrophenylamine or
2-Ethyl-6-Nitroaniline, C₆H₅C₂H₅(NO₂)NH₂;
mw 166.18, N 16.86%; crspts, mp 32 °C, bp 151-3 °C
(6 mm Hg). Prep by nitrating 2-ethylacetani-
lide in HAc/Ac₂O followed by removal of the CH₃CO-with acid
Refs: 1) Beil, not found  2) L. J. Sargent,
JOC 19, 599-607 (1954) & CA 49, 5478 (1955)

2-Ethyl-2-nitrophenylamine or
3-Ethyl-2-Nitroaniline, C₆H₅C₂H₅(NO₂)NH₂;
mw 166.18, N 16.86%; orn-red crspts, mp
32-33 °C. Prep by reducing 2,3-dinitroethyl-
benzene with stannous chloride in ethanolic
HCl
Refs: 1) Beil, not found  2) H. Kondo & S.
Uyee, Ber 70B, 1087-93 (1937) & CA 31,
4981 (1937)

ETHYLPHENYLAMINES AND DERIVATIVES
Ethylphenylamines or Aminoethylbenzenes,
also known as o-m-and p-Ethylanilines,
C₆H₅C₂H₅NH₂ (Not to be confused with
N-Ethylaniines), mw 121.18. All three iso-
mers are described in the literature
Refs: 1) Beil 12, 1089, (468) & [584], (ortho)
2) Beil 12, 1090 & (468) (meta)  3) Beil 12,
1090 (469) & [584] (para)
4-Ethyl-2,6-dinitrophenylamine or 4-Ethyl-2,6-dinitroaniline, \( \text{C}_2\text{H}_5\text{CN}_{2}\text{H}_2(\text{NO}_2)\text{NH}_2 \); mw 211.18, N19.90%; mp 75.5\(^\circ\); sol in chloroform and benzene. Prepd by heating the corresponding acetanilide in HCl. 

Refs: 1) Beil, 12, 1092 & [585]; 2) H. Paucksch, Ber 17, 760 (1884).

4-Ethyl-3,5-dinitrophenylamine or 4-Ethyl-3,5-dinitroaniline, \( \text{C}_2\text{H}_5\text{C}_8\text{H}_4(\text{NO}_2)\text{NH}_2 \); mw 211.18, N19.90%; mp 75.5\(^\circ\); sol in chloroform and benzene. Prepd by heating the corresponding acetanilide in HCl. 

Refs: 1) Beil, 12, 1092 & [585]; 2) G. Schultz & A. Sander, Ber 42, 2634 (1909); 3) O. L. Brady et al., JCS 1928, 980 & CA 22, 2353 (1928).

N-Ethyl-N-nitrosoguanidine or N-Ethyl-N,N-dinitroguanidine. Prepd by benzanilide. Prepd by heating the corresponding acetanilide in HCl. 

Refs: 1) Beil, 12, 1092 & [585]; 2) O. L. Brady et al., JCS 1928, 980 & CA 22, 2353 (1928).

N-Ethyl-N,N-dinitroguanidine or Ethyl Tetryl. See this Vol, p E207-L. The following information was not included there: 

1) Desseigne prepd by reacting ethylamine with dinitrochlorobenzene, followed by mixed acid nitration at 40-50\(^\circ\). 
2) Ethyl Tetryl forms a eutectic, mp 75.5\(^\circ\) with Tetryl (60-70% ET / 30-40% T). 
3) It is stable to Able Test at 80\(^\circ\). 
4) Impact Sensitivity - 48% detonations with 2kg wt falling 2.5 meters.
5) Initiation Sensitivity — 0.40g MF detonate
30mm diam cartridge contg 50g sample at
sp gr 1.65
N-Ethyl-N,2,3,4,6-Pentanitroaniline. See
this Vol, p E207-R. It is an expl compd

N-(2-Nitroethyl)-N,2,4,6-Tetranitroaniline
or Pentryl. See Vol I, p A425-L

Ethylphenylcarbamate and Derivatives

Ethylphenylcarbamate or N-Phenylurethane,
C₆H₅-NH·COOC₂H₅; mw 165.19, N8.48%;
wh crysts with aromatic odor, sp gr 1.106 at
20/4°, mp 52-53°, bp 237° (sl decomps); ins
sol in cold w; sol in alc, eth & boiling w.
Can be prepd by the action of ethanol on
phenyl isocyanate
Can be nitrated to prep expl compds
Refs: 1)Beil 12, 320, (218) & [184] 2)
Wilm & Wischin, Ann 147, 157 (1868) 3)
CondChemDict (1961), 476-L

Ethyl-2-nitrophenylcarbamate,
O₂NCH₄-NH·COOC₂H₅; mw 210.19, N13.33%;
yel prisms (pet eth), yel ndls (alc), mp 58°,
sol in benz & ligroin. Prepd by heating
2-nitroaniline with ethylchlorofomate in chl
Refs: 1)Beil 12, 694 [372] 2)C.Rudolph,
Ber 12, 1295 (1879)

Ethyl-3-nitrophenylcarbamate,
O₂NCH₄-NH·COOC₂H₅; mw 210.19, N13.33%;
yel ndls, mp 57° (65°), sol alc, eth, chl, benz,
acet. Prepd from 3-nitrobenzamide, bromine
and sodium alcoholate
Refs: 1)Beil 12, 706 2)E.Jeffreys, AmChemJ
22, 41 (1899)

Ethyl-4-nitrophenylcarbamate,
O₂NCH₄-NH·COOC₂H₅; mw 210.19;N13.33%;
ndls(benz), mp 132°, sol in alc & benz. Prepd
by treating 4-nitrobenzoic acid bromamide in
alc with sodium alcoholate
Refs: 1)Beil 12, 723 & [392] 2)S.E.Swatrz,
AmChemJ 19, 301 (1897)

Ethyl-2,4-dinitrophenylcarbamate,
(O₂N)₂C₆H₄-NH·COOC₂H₅; mw 255.19,
N16.47%; yel-brn ndls (alc), mp 110-115°, sol
in alc. Prepd by treating the parent with HNO₃
in the cold
Refs: 1)Beil 12, 755,(363) & [410] 2)
P.van Rombourgh, RecTravChim 10, 141 (1891)

Ethyl-3,5-dinitrophenylcarbamate,
(O₂N)₃C₆H₄-NH·COOC₂H₅; mw 255.19,
N18.57%; ndls, mp 83°. Prepd by reacting
phosgene with 3,5-dinitroaniline to give 3,5-
dinitrophenyl isocyanate, which was reacted
with alc
Refs: 1)Beil, not found 2)J.J.Blanksma &
G.Verberg, RecTravChim 53, 1037-46 (1934)
& CA 29, 463 (1935)

Ethyl-N-nitro-3,5-dinitrophenylcarbamate,
(O₂N)₃C₆H₄-N(NO₂)·COOC₂H₅; mw 300.19,
N18.68%, OB to CO₂-74.7%, col ndls, mp
102°. Was prepd by nitrating 3,5-Dinitrophenyl-
carbamate with absolv nitric acid at -15°,
a small amt of a by-product was produced
at the same time (mp 118°).
Explosive props were not examined
Refs: 1)Beil, not found 2)J.J.Blanksma &
G.Verberg, Rec 53, 1042-43 (1934) &
CA 29, 469 (1935)

Ethyl-2,4,6-trinitrophenylcarbamate or
Picrylurethane

(O₂N)₃C₆H₄-NH·COOC₂H₅; mw 300.19,
N18.67%, OB to CO₂-74.7%, ndls (dil alc)
or plates (conc'd alc), mp 147°. Prepd from
the parent or the 2,4-dinitro derivative by
warming with sp gr 1.5 HNO₃, or by treating
with mixed acid, cold. This compd is expl
Refs: 1)Beil 12, 768,(370) & [423] 2)P.
v.Rombourgh, RecTravChim 10, 142 (1891)

Ethyl-2,3,5-trinitrophenylcarbamate,
(O₂N)₃C₆H₄-NH·COOC₂H₅; mw 300.19,
N18.67%, OB to CO₂-74.7%, yel lfts, mp 118°
Was prepd by nitrating Ethyl-3,5-dinitrophenyl-
carbamate with mixed nitric-sulfuric acid
at -15°, a small amt of a by-product isomer
melting at 144° was obtd at the same time;
the by-product was not identified. This compd
is expl
Refs: 1)Beil, not found 2)J.J.Blanksma &
G.Verberg, Rec 53, 1044-45 (1934) &
CA 29, 463 (1935)

Ethylphenylcarbamate, Ethyl Ester or Ethyl-
Phenylurethane. (Áethylphenylcarbamidsäure-
äthylester, in Ger), C₆H₅.N(C₂H₄).COOC₂H₅; mw 193.25; N 7.25%; col oil, sp gr 1.0436 at 20/4°, bp 130° at 14mm or 137.5-138° at 19mm, N p 1.50573 at 20°; solubilities are given in Ref 3. Can be prepd from ethylaniline, ethylchloroformate and sodium bicarbonate in ice water.

Tavernier (Ref 4) reported its heat of combustion as 7561 cal/g at C₂, heat of formation 409 cal/g at C₂, and 437 at C₂. It was used by the Germans, especially in Nitroguanidine propellants.


Ethylphenylglycinate and Derivatives
Ethylphenylglycinate or N-Phenylglycine
Ethylester, C₆H₅.NH.CH₂.COOC₂H₅; mw 179.21, N 7.82%; iffs, mp 57-58°, bp 273° (sl decomp); v sl sol in hot w; v sol in hot alc; v sol in eth. Can be prepd by warming ethylchloroacetate with aniline.

Refs: 1) Beil 12, 470, (263) & [249] 2) P.J. Meyer, Ber 8, 1156 (1875)

Ethyl-2-nitrophenylglycinate,
O₂N.C₆H₅.NH.CH₂.COOC₂H₅; mw 224.21, N12.50%; yel crystals, mp 77-8°. Prepd by heating ethyl bromoacetate with 2-nitroaniline.


Ethyl-3-nitrophenylglycinate,
O₂N.C₆H₅.NH.CH₂.COOC₂H₅; mw 224.21, N12.50%; crysts (alc), mp 84°. Prepd by boiling 3-nitroaniline with ethylchloroacetate in a little alc.


Ethyl-4-nitrophenylglycinate,
O₂N.C₆H₅.NH.CH₂.COOC₂H₅; mw 224.21, N12.50%; crysts (alc), mp 132-4°. Prepd by heating ethyl bromoacetate with 4-nitroaniline and sodium acetate.


Ethyl-2,4-dinitrophenylglycinate
(O₂N)₂C₆H₅.NH.CH₂.COOC₂H₅; mw 269-21, N15.61%; gr yel ndls (alc), mp 144°, sol in HAc & cold acet. Prepd by heating 2,4-dinitrochlorobenzene with ethyl glycolate and hydrochloride in alkaline alc.


Ethyl-2,4,6-trinitrophenylglycinate,
(O₂N)₃C₆H₅.NH.CH₂.COOC₂H₅; mw 314.21, N17.83%. Apparently prepd by Gidaspov, (Ref 2), but no details are given in CA. This compd is an expl.


Ethylphenylglycinamide-o-carboxylate (Phenylglycinamide-o-carboxylate-äthylester in Ger), C₆H₅NH.CH₂.COO.N$: mw 248.24, N22.57%; oily liquid, violently ex- exploding. Prepd by treating with HNO₃ the hydrazide, which came from heating hydrazine hydrate with ethyl-2-carbethoxyphenylglycinate.

Refs: 1) Beil, not found 2) Th. Curtius, J.Prakt Chem 125, 111 & 136 (1930) & CA 24, 3233 (1930)

Ethylphenylhydrazine and Derivatives
Two isomers are listed in Beil: Ethylphenylhydrazine (a,a), C₆H₅.N(C₂H₄).NH₂; mw 136.19, N20.57%; oil, sp gr 1.018 at 15°, bp 237°; soly is not given. Prepn is described in Ref 1.

Ethylphenylhydrazine (a, β), C₆H₅.NH.NH.C₂H₅, mw 136.19, N20.57%
oil, sp gr 1.004 at 15/15°, bp 237-40° (in nitrogen), sl sol in w, v sol in alc or eth. Prepn is described in Ref 2
Ref: s) 1)Beil 15, 119, (27) & [50] 2) Beil 15, 120 & [50]

1-Ethyl-1-(4-nitrophenyl)hydrazine
O₂N₃C₂H₅.N(N₃C₆H₄).NH₂; mw 181.19, N23.19%; yel crysts (pet eth), mp 74°. Prepd by boiling with concd HCl the product from the reaction of EtI with p'-O₂N₃C₆H₄.NH₂:CH₂₇H₆ (K salt)
Ref: s) 1)Beil, not found 2)V.R.Ciusa & G.Rastelli, Gazz 54, 72-8 (1924) & CA 18, 2139 (1924)

1-Ethyl-1-(2,4-dinitrophenyl) hydrazine,
(O₂N₃)₂C₆H₄.N(N₃C₆H₂).NH₂; mw 226.19, N24.77%; yel ndls (alc), mp 98-100°. Prepd by heating with concd HCl the product from the reaction of EtI with 2,4-(O₂N₃)₂C₆H₄.NH₂:CH₂₇H₆ (K salt). Forms a Picrate salt, yel ndls (50% alc), mp 90-2°
Ref: 1)Beil, not found 2)M.Ragno, Gazz 75, 200-4 (1945) & CA 41, 4127 (1947)

Ethyl-2,4,6-trinitrophenyl-hydrazine or Ethyl-
Picryl hydrazine (Not known if it is the 1,1- or
the 1,2-isomer), (O₂N₃)₂C₆H₄.NH₂:CH₂₇H₆ (C₆H₂);
mw 271.19, N25.83%; yel plates (chlf), mp 200° (sl dec), sol in alc, concd HCl. Prepd from ethylhydrazine and picryl chloride in cold alc
Ref: 1)Beil 15, 493 2)E.Fischer, Ann 199, 299 (1879)

1-(2,2,2-Trinitroethyl)-2-(2,4-dinitrophenyl)hydrazine,
(O₂N₃)₂C₆H₄.NH₂.NH.CH₂₇C(NO₂)₃; mw 361.19
N27.15%, OB to CO₂-42.1%, crysts, mp 95-6°
Prepd by heating CH(NO₂)₃ in chlf with the
2,4-dinitrohydrazine of formaldehyde. Nitration in Ac₂O at 10-15° gave a product, mp
133-4°, not ring nitrated, but not further examined. This compd is expl

1-(2,2,2-Trinitroethyl)-2-(2,4,6-trinitrophenyl)
hydrazine,
(O₂N₃)₂C₆H₄.NH₂.NH.CH₂₇C(NO₂)₃; mw 406.19,
N27.59%, OB to CO₂-27.6%; crysts, mp 120-1°.
Prepd by heating CH(NO₂)₃ in chlf with the 2,4,6-trinitrophenylhydrazine of formaldehyde. This compd is expl

Ethylphenyl Ketone or Propiophenone,
C₆H₅.CO.CH₂₇H₆; mw 134.17; water-white to
sl amber liq with strong odor; sp gr 1.012 at
20/20°, congealing temp 17.5-21°, nD₂0 1.527 at
20°, fl p (TCC) 210° F; insol in w, glycol or
glycerine; miscible with alc, eth, benz or
toluene. Can be prepd by heating HCl with the
product (2CH₆H₄+3H₂O+3H₂Cl) arising from aqueous HgCl₂ and a-phenylallylene
Used as starting material for prepn of ephedrine, several other pharmaceuticals and
numerous organic chemicals (Ref 3)
Ref: s) 1)Beil 7, 300, (159) & [231] 2) A.
Körner, Ber 21, 277 (1888) 3)CondChemDiet
(1961), 945-L (Propiophenone); 8th edit (1971),
733-R to 734-L (Propiophenone)

Ethylphenylureas and Derivatives
N,N'-Ethylphenylurea
C₆H₅.NH.CO.NH₂:CH₂₇H₆; mw 164.20,N 17.06%;
ndls (from ac alc), mp 99°; sol in alc Can be prepd from aniline and ethylisocyanate
Ref: s) 1)Beil 12, 348, (231) & [205] 2)A.
Wurz, Répertoire de Chimie Pure 4, 203
(1862)

N,N'-Ethylphenylurea,
C₆H₅.N(CH₂₇H₆).CO.NH₂; mw 164.20, N17.06%;
plates (pet eth), mp 62°, v sol in w and organ-
ics. Prepd from N-ethylamine .HCl and po-
tassium cyanate
Ref: 1)Beil 12, 422 & [237] 2)W.Gebhardt,
Ber 17, 2095 (1884)

N-(2-Azidoethyl)-N'-phenylurea,
N₈.CH₂₇H₆.NH.CO.NH₂:CH₂₇H₆; mw 205.22,
N34.13%; ndls (benz), mp 99°, sol in cold alc,
EtAc, chlf & hot benz. Prepd from 2-azido-
ethylamine and phenylisocyanate in benz

N-Ethyl-N'-(2,4-dinitrophenyl)urea,
C₆H₅.NH.CO.NH:C₆H₃(NO₂)₃; mw 254.20,
N22.04%; crysts, mp 161°. Prepd by heating
N-Nitro-N’(2,4-dinitrophenyl)urea with ethylamine in alc

**N-Ethyl-N’-(3,5-dinitrophenyl)urea,**
\[ \text{C}_2\text{H}_5\text{NH.CO.NH.C}_6\text{H}_4\text{(NO}_2\text{)}_2 \]  mw 254.20, N22.04%; crystals, mp 155°. Prepd by heating ethylisocyanate with 3,5-dinitroaniline at 120° in a sealed tube, or by reacting ethylamine with 3,5-dinitrophenylisocyanate
Refs: 1) Beil, not found 2) J.J. Blanksma & G. Verberg, Rec 53, 1037-46 (1934) & CA 29, 463 (1935)

**N-Ethyl-N-nitro-N’-(2,4-dinitrophenyl)urea,**
\[ \text{C}_2\text{H}_5\text{N(NO}_2\text{)}_2\text{.CO.NH.C}_6\text{H}_4\text{(NO}_2\text{)}_2 \]  mw 299.20, N23.41%; crystals (pptd from acet with pet eth), mp 90-9.5° (dec), sol in acet & chlor. Prepd from the parent and 100% HNO₃ at -15°, then ambient temp
Refs: 1) Beil 12, 411 2) L.C.E. Kniphorst, Rec 44, 696, 717 (1925) & CA 20, 589 (1926)

**N-Ethyl-N-nitro-N’-(3,5-dinitrophenyl)urea,**
\[ \text{C}_2\text{H}_5\text{N(NO}_2\text{)}_2\text{.CO.NH.C}_6\text{H}_4\text{(NO}_2\text{)}_2 \]  mw 299.20, N23.41%; crystals, mp 98°. Prepd by treatment of N-ethyl-N’-(3,5-dinitrophenyl)urea with 100% HNO₃ at -15°
Refs: 1) Beil, not found 2) J.J. Blanksma & G. Verberg, Rec 53, 1037-46 (1934) & CA 29, 463 (1935)

**N-(2,2,2-Trinitroethyl)-N’-phenylurea,**
\[ (\text{O}_2\text{N})_2\text{C}_6\text{H}_4\text{NH.CO.NH.C}_6\text{H}_4\text{.} \]  mw 299.20, N23.41%; crystals, mp 1.51, mp 162°, bp ignites above 418°. Prepd by refluxing phenylurea with excess trinitroethanol in methanol for 3 hours (Ref 2). Its sensitivity to impact is about that of Comp B

**N-Ethyl-N-nitro-N’-(2,4,6-trinitrophenyl)urea,**
\[ \text{C}_2\text{H}_5\text{N(NO}_2\text{)}_2\text{.CO.NH.C}_6\text{H}_4\text{(NO}_2\text{)}_3 \]  mw 344.20, N24.42%, OB to CO₂ -60.5%; crystals, mp 60-105° (dec), unstable. Prepd from the parent and mixed acid


**Ethylphosphate and Derivatives**
*Ethylphosphate or Triethylphosphate,*
\[ (\text{C}_2\text{H}_5\text{O})_3\text{PO} \]  mw 182.16, col liq, sp gr 1.068 at 20/4°, fl p 240°F (115.6°), nD 1.4055 at 20° sol in alc, eth and in most common org solvents, sol in w- the solas are stable at ord temp, but slowly hydrolyze when hot; compatible with many gums and resins. Can be prepd by heating lead diethylphosphate
Used as a high-boiling solvent; as plasticizer for resins, gums; in manuf of plasticides and as catalyst (Ref 3)

**Tris-(2-nitroethyl)phosphate,**
\[ (\text{O}_2\text{NCH}_2\text{CH}_2\text{O})_3\text{PO} \]  mw 317.15, N13.25%, OB to CO₂ 53.0%; liq, sp gr 1.752 at 30/4°, bp 159-160° (3.5 mm Hg), nD 1.4471 at 25°. Prepd by reacting POCl₃ with 2-nitroethanol
Tris-(trinitroethyl)phosphatate or Trinitrotrotrinitroethyphosphatate, $\text{OP}_{3}\text{C}_{3}\text{H}_{2}\text{C}(\text{NO}_{2})_{2}$, mw 587.14, N21.47%; OB to CO$_2$ at 12.3% crysts, sp gr 1.74, mp 126°, bp ignites at 235°, solv (?:). Was prepd at Hercules Powder Co laboratory by the action of phosphorus penta-chloride on Trinitroethanol (Ref 2).

It is an exp with impact sensitivity about that of Pentolite; its vacuum stability at 100° was 4.8 ml gas evolved per gram in 48 hours.


Ethylphosphorodimethylamidycyanodate. See GA Chemical Warfare Agent in Vol 2, p C167-R. Originally it was German Agent of World War II, called Tabun, Trilon B3, B8 or T100, described in PATR 2510 (1958), p 48, Ger 204-L

Ethylphthalate or Palatinol A. See o-Dioctyl phthalate in Vol 5 of Encycl, pD1248-L.

As its nitro-compds are not listed there, we are describing them here:

3-Nitro Ethylphthalate,

$$(\text{O}_2\text{N})_3\text{C}_2\text{H}_4\text{C}(\text{O}_2\text{C}_2\text{H}_4)_2$$; mw 267.24, N5.24%; prisms (alc), mp 45°, insol in w, sol in alc & eth. Prepd by esterification of the acid in hot alc with HCl.

Refs: 1) Beil 9, 260, (368) & (606) 2) O. Miller, Ann 206, 243 (1881)

4-Nitro Ethylphthalate,

$$(\text{O}_2\text{N})_3\text{C}_2\text{H}_4\text{C}(\text{O}_2\text{C}_2\text{H}_4)_2$$; mw 267.24, N5.24%; plates (alc), mp 33-4°, bp 140° (0.01 mm Hg) & 213° (17 mm Hg). Prepd from esterification of the acid in alc with HCl.

Refs: 1) Beil 9, 831 & (607) 2) O. Miller, Ann 208, 227, 234 (1881)

5-Nitro Ethylisophthalate,

$$(\text{O}_2\text{N})_3\text{C}_2\text{H}_4\text{C}(\text{O}_2\text{C}_2\text{H}_4)_2$$; mw 267.24, N5.24%; ndls (alc), mp 83.5°, sl sol in w or cold alc, sol in hot alc. Prepd by refluxing the acid in alc with HCl.

Refs: 1) Beil 9, 840 2) H.E. Storrs & R. Fittig, Ann 153, 288 (1870)

4,6-Dinitro Ethylisophthalate,

$$(\text{O}_2\text{N})_3\text{C}_2\text{H}_4\text{C}(\text{O}_2\text{C}_2\text{H}_4)_2$$; mw 312.24, N8.97%; crysts, mp 109°. Prepd from the diacid chloride by treatment with alc.

Refs: 1) Beil, not found 2) H. Goldstein & J.P. Merminod, Helv Chim Acta 35, 1476-80 (1952) & CA 47, 4868 (1953)

2,5-Dinitro Ethylterephthalate,

$$(\text{O}_2\text{N})_3\text{C}_2\text{H}_4\text{C}(\text{O}_2\text{C}_2\text{H}_4)_2$$; mw 312.24, N8.97%; ndls (alc), mp 144°, sol in alc, eth & benz. Prepd by esterification of the acid.

Refs: 1) Beil 9, 853 2) C.Haussermann & E. Mertz, Ber 26, 2984 (1893)

Bis-(Nitroethyl)-phthalate or Dinitrodiethylphthalate, $\text{C}_9\text{H}_4\text{[CO}_2\text{CH}_2\text{CH}_2\text{NO}_2]_2$; mw 312.24, N8.97%; liq, sp gr 1.652 at 30/3°, bp 179-82° (4 mm Hg), d$_3$1.5347 at 25°. Prepd by heating phthalic anhydride with 2-nitroethanol in glucose containing colyn sulfonic acid.


Bis (Trinitroethyl)-phthalate or Hexanitrodiethyl-phthalate, $\text{C}_9\text{H}_4\text{[CO}_2\text{CH}_2\text{C(NO}_2)_3]_2$; ortho derivative; mw 492.23, N17.07%, OB to CO$_2$ at 39.0%, crysts, sp gr 1.62, mp 125°, bpignites at 267°. Can be prepd by heating the acid chloride of diethylphthalate with trinitroethanol (Ref 2) or from the same reactants in carbon tetrachloride at 30° in the presence of Friedel-Crafts catalysts, such as AlCl$_3$ (3).

It is explosive with sensitivity to impact comparable to Tetryl.

Ethylpicramide. See N-Ethyl-2,4,6-trinitroaniline, under N-Ethylaniline in this Vol

Ethyl Picrate. See 3-Ethyl-2,4,6-trinitrophenol under ETHYLPHENOLE AND DERIVATIVES in this Vol

Ethyl Picrate Nitramine. See 3-Ethyl-2,4,6-trinitrophenol Nitramine under ETHYLPHENOLE AND DERIVATIVES in this Vol

Ethylpicryl Nitramine. Same as Ethylpicrate Nitramine

Ethylpropanediol and Derivatives
2-Ethyl-1,3-propanediol or Ethyltrimethylene-glycol, HO.CH₂.CH(C₂H₅).CH₂OH, mw 104.15 liq, bp 124-7° (16 mm Hg). Prepd by the lithium aluminum hydride reduction of 2-ethyl diethylmalonate

2-Nitro-2-ethyl-1,3-propanediol (NEP), HO.CH₂.NO₂(C₂H₅).CH₂OH, mw 149.15, N9.39%, ndls (w), mp 57-8°, sol in w, alc & eth. Was first prepd by Pauwels (Ref 2) on condensation of formaldehyde with 1-nitropropane in presence of K carbonate. Vanderbilt & Hass (Ref 3 & 4) described methods of prep of yields up to 96% using formaldehyde, 1-nitropropane and tertia amine or alkali hydroxides. Médard (Ref 5) and Médard & Thomas (Ref 6) deter its heats of combustion (703.7 kcal/moles) and formation. Médard also described its prep and properties

2-Nitro-2-ethyl-1,3-propanedinitrate Dinitrate, (O₂NO)₂CH₂.CNO₂(C₂H₅)₂CH₂(OONO₂), mw 239.15, N17.57%, OB to CO₂ - 43.5%; pale yel liq; sp gr 1.443 at 20/20°, bp - explodes; nD 1.4734 at 20°; sl sol in w. Was prepd by Médard (Ref 2) by nitration technical 2-Nitro-2-ethyl-1,3-propanedinitrate with mixed acid. For this he added in small portions, with stirring, 25g of NEP to 100g of mixed acid (HNO₃ 40 & H₂SO₄ 60%) precooled to 0° and allowing the temp to rise to ca 8° at the end of addition. The stirring was continued until the temp reached 15° and then the mixt was poured into 600 ml of w at ca 50°. After washing the oil, first with w and then with dil Na bicarbonate soln, it was dried in a desiccator over Ca chloride. The yield was 92% of theory

Following props are listed in Refs 2&3:

Gelatinizing Action on NC-practically none even after 8 days at 50°
Gelatinizing Action on Polyvinyl Acetate-complete
Heat of Combustion at C_p = 693.5 kcal/kg
Heat of Combustion at C_V = 691.5 kcal/kg
Heat of Formation at C_V = 82.7 kcal/kg
Heat of Formation at C_p = 88.5 kcal/kg
Impact Sensitivity - sl less sensitive than NG
Initiation Sensitivity - placed in a glass tube 17mm diam could not be initiated even by means of Briska Cup
Power by French Lead Block Test (Cup)= 125% of PA
Viscosity - 49 centipoises vs 35 cps for NG at 20°
Volatility - 10g sample left in a crystallizer at 40° for several days showed average loss of 1.08 mg per square decimeter of surface. This value is just slightly below that for NG Uses - Several expl mixtures based on the dinitrate and AN were prepd and examined in France. Most of these mixtures were very difficult to initiate
Refs: 1) Beil, not found  2) L. Médard, MP
35, 149 (1953) & CA 49, 5843 (1955)
3) L. Médard & M. Thomas, MP 35, 157 &
172 (1955) & CA 49, 11284 (1955)

Ethylpropionate or Propionic Ester,
C₆H₅·COOC₂H₅; mw 102.10, col, flammable
liq with odor resembling pineapple; sp gr
0.896 at 15/4°C; fr p -73°C, bp 99.1°C, nD
1.3844 at 20°C, f1 p 12°C; sc soln in w; miscible with alc
& eth. Can be prep'd by treating ethanol with
propionic acid. Used in flavoring syrups, as
solvent for cellulose ethers & esters and for
various resins; also as a cutting agent for pyr-
roxol
Refs: 1) Beil, 2, 240 2) CondChemDict
3) Sax, 3rd edit (1968), 761-L

2-Ethyl-3-propyl-acrolein or 2-Ethylhexen-
2-al, C₈H₁₇·CH=C(CH₃).CHO; mw 126.19,
It yel liq with strong unpleasant odor, sp gr
0.81518 at 20/20°C, bp 175.0°C at 760 mm, fl
P -159°C, vapor pressure 1.0 mm at 20°C, vis-
cosity 0.113 poises at 20°C. Can be prep'd by
shaking butyraldehyde with w and 10% NaOH,
Used in org synthesis (as intermediate), insecticide and in
warning agents and leak detectors
Refs: 1) Beil 1, 744 & [799] 2) G.A. Rau-
penstrauch, Monatsch 8, 112 (1887) 3) Cond
761-R 4) Sax, 3rd edit (1968), 374-L

Ethylpropylamine and Derivatives
Ethylpropylamine,
H₃C·CH₂·HN·CH₂·CH₃·CH₃; mw 87.16, col
liq, sp gr 0.773 at 24°C, bp 79.8°C (747 mm Hg),
sol alc, other organics, diff sol w. Prep'd by
heating in a closed tube at 125-140°C 33%
aq ethylamine with propyl chloride
Refs: 1) Beil 4, 138, (361) & [621] 2) E.
Comaducci & M. Arena, ChemZentr 1907
II, 1396

N-Nitro Ethylpropylamine,
H₃C·CH₂·NO₂·CH₂·CH₃; mw 132.16,
121.20%; col liq, sp gr 1.028 at 15°C, bp 108°C
(22 mm Hg). Prep'd from propyl iodide and the
potassium salt of ethyl nitramine
Refs: 1) Beil 4, 146 2) H. Umbgrove & A.P.N.
Franchimont, Rec 17, 274 (1878)

Ethyl-2,2-dinitropropylamine Nitrate,
H₃C·CH₂·NH·CH₂·C(NO₂)₂·CH₃·HNO₃; mw
240.17, N23.33%, OB to CO₂-60%; crs
mp 111-112°C. Prep'd by condensing ethylamine
with 2,2-dinitropropanol to give the free base
(which tends to revert to starting material),
followed by addition of 70% HNO₃ in eth
Refs: 1) Beil, not found 2) H.E. Ungnade
& L.W. Kissinger, JOC 30(2), 357 (1965) & CA
62, 9043 (1965)

N-Nitro Ethyl-2,2-dinitropropylamine,
H₃C·CH₂·N(NO₂)₂·CH₃·C(NO₂)₂·CH₃; mw
222.16, N25.22%, OB to CO₂-64.9%; crs,
mp 82-3°C. Prep'd by treating the preceding compd
with 100% HNO₃ in Ac₂O at 0-54°C
Refs: 1) Beil, not found 2) H.E. Ungnade
& L.W. Kissinger, JOC 30(2), 357 (1965) & CA
62, 9043 (1965)

2,2,2-Trinitroethyl-3,3,3-trinitropropylamine,
C(NO₂)₃·CH₂·NH·CH₂·CH₂·C(NO₂)₃; mw
357.15, N27.45%, OB to CO₂-6.7%; crs,
mp 64.5°C(chill). Prep'd from trinitroethanol
and trinitropropylamine hydrochloride in aq
base
Refs: 1) Beil, not found 2) M.B. Frankel
& K. Klager, J ChemEngData 7, 412-13 (1962)
& CA 57, 10993 (1962)

N-(2,2,2-Trinitroethyl)-N-(2,3,3-trinitropropyl)nitramine or Heptanitropropylamine,
(O₂N)₈·C·CH₂·N(NO₂)₃·CH₃·CH₂·C(NO₂)₈; mw
402.15, N27.86%, OB to CO₂+ 4.0%; crs,
sp gr 1.83, mp 144-145°C bp - ignites at 190°C (by
hot bar method). Prep'd by treating the preceding
compd with 100% HNO₃ and Ac₂O at 0°C
ambient temp. Impact sensitivity is comparable
to that of PETN
Refs: 1) Beil, not found 2) J.T. Carleton &
M.B. Frankel, Aeroguet General Corp Rept No
660 (1952), Explosives Research Contract
No 7-onr-46208 3) D.V. Sickman & W.F. Sagger,
NAVORD Rept 486 (1954), Res & Devel
in New Chem High Exppls 4) M.B. Frankel &
K. Klager, J ChemEngData 7, 412-13 (1962)
& CA 57, 10993 (1962)
Ethyl-isopropylaniline and Derivatives

**N-Ethyl-isopropylaniline**, 
\( \text{C}_8\text{H}_8\text{N}(\text{C}_2\text{H}_3)(\text{C}_4\text{H}_8) \); mw 163.25, N8.58%; liq, sp gr 0.9343 at 15°, bp 214-15°. Prepd from ethylaniline and 1-propyl iodide

*Refs:* 1) Beil 12, 167 2) J.V.Braun, Ber 33, 2732 (1900)

**N-Ethyl-(2-nitro-iso-propylaniline, Hydrochloride**, 
\( \text{C}_8\text{H}_8\text{N}([\text{C}_2\text{H}_3]_2\text{CH}(\text{C}_3\text{H}_3)\text{CH}_2\text{NO}_2\text{HCl} \); mw 244.73, crystals, mp 123°. Prepd from 1-nitropropene and ethylaniline and isolated as the HCl salt


2,3,6-Trinitro-N-ethyl-isopropylaniline or Picryl Ethylisopropylamine,
\( \text{C}_8\text{H}_8\text{N}([\text{NO}_2]_2\text{N}(\text{C}_2\text{H}_3)(\text{n-C}_7\text{H}_15) \); mw 298.26, N18.79%; red, ndls or yel plates (from alc or alc/HAc), heating the red at 90° converts it to the yellow which has mp 108-9° (isomerism probably due to restricted rotation of the aromatic C-N bond). Prepd by heating picrnyl chloride with ethylisopropylamine in alc

*Refs:* 1) Beil 12, 764 2) A.Mulder, Rec 25, 114 (1905)

Ethyl-N-propylaniline and Derivatives,

**N-Ethyl-N-propylaniline**, 
\( \text{C}_8\text{H}_8\text{N}(\text{C}_2\text{H}_3)(\text{n-C}_7\text{H}_15) \); mw 163.25, N8.58%; liq, bp 107° (14 mm Hg), 216°. Prepd from ethylaniline and propylbromide

*Refs:* 1) Beil 12, 167, (159) & [94] 2) A. Claus & H.Hirzel, Ber 19, 2787 (1886)

**N-Ethyl-(2-nitropropylaniline Hydrochloride**, 
\( \text{C}_8\text{H}_8\text{N}(\text{C}_2\text{H}_3)\text{CH}(\text{NO}_2)\text{CH}_3\text{HCl} \); mw 244.73, mp 126°. Prepd from 2-nitropropane and ethylaniline


2,4-Dinitro-N-ethylpropylaniline,
\( \text{C}_8\text{H}_8\text{N}([\text{NO}_2]_2\text{N}(\text{C}_2\text{H}_3)(\text{n-C}_7\text{H}_15) \); mw 253.26, N16.59%; or-yel plates (alc), mp 55°, sp gr 1.343 at 10°. Prepd by refluxing in alc a mixture of ethylaniline and 2,4-dinitro-bromoaniline


2,6-Dinitro-N-ethylpropylaniline,
\( \text{C}_8\text{H}_8\text{N}([\text{NO}_2]_2\text{N}(\text{C}_2\text{H}_3)(\text{n-C}_7\text{H}_15) \); mw 253.26, N16.59%; crystals, mp 38-40°. Prepd by reacting ethylaniline with 2,6-dinitrochlorobenzene

*Refs:* 1) Beil, not found 2) E.Lilly & Co, Brit P917253 (1963) & CA 59, 9889 (1963)

Ethylpyridines and Derivatives

**2-Ethylpyridine**, \( \text{C}_8\text{H}_8\text{C}_2\text{H}_4\text{N} \); mw 107.15, N13.07%; liq, sp gr 0.9371 at 17°, bp 148.7°, diff soln in w. Prepd by heating N-ethylpyridine iodide in a tube at 300°

*Refs:* 1) Beil 20, 241 & [159] 2) A. Ladenburg, Ber 16, 2059 (1883)

**2-(2-Azidoethy)pyridine**, \( \text{N}_8\text{CH}_2\text{CH}_2\text{C}_2\text{H}_4\text{N} \); mw 148.17 N37.81%; liq, sp gr 1.1122 at 20/4°, bp 65° (1 mm Hg), n D 1.5289 at 25°. Prepd by reacting HN\(_3\) with 2-vinylpyridine in aq HAc; there is a Picrate, yel ndls (alc), mp 112-15°

*Refs:* 1) Beil, not found 2) J.H. Bayer, JACS 73, 5248-52 (1951) & CA 47,490 (1953)

**2-(2-Nitroethyl)pyridine**, \( \text{O}_2\text{NCH}_2\text{CH}_2\text{C}_2\text{H}_4\text{N} \); mw 152.15, N18.41%; crystals, mp 145° (alc). Prepd by reacting HNO\(_3\) with 2-vinylpyridine at 60°(Ref 2).

Ref 3 [prepn by NaBH\(_4\) reduction of 2-(2-nitrovinyl)pyridine] states that the material is unstable in air, likewise an HCl salt (mp 106-8°), but that a Picrate salt (mp 129-30° dec) does analyze properly


**2-Ethyl-5-nitropyridine**, \( \text{C}_8\text{H}_8\text{N}([\text{NO}_2]_2\text{C}_2\text{H}_4\text{N} \); mw 152.15, N18.41%; liq, bp 69° (0.3 mm Hg). Prepd by reacting 2-chloro-5-nitropyridine with sodium diethylalcoholate in tetrahydrofuran, followed by decarboxylation by heating in dil sulfuric acid

3-Ethylpyridine, \( \text{C}_3\text{H}_7\text{N} \); mw 107.15, N13.07%; liq, sp gr 0.9401 at 22.5/4\(^\circ\); bp 165.9\(^\circ\), n\(D\) 1.5021 at 22.5\(^\circ\), dif sil in w; sol in alc & eth; stream distils. Prepd by distillation of glycine with ammonium phosphate


3-Ethyl-4-nitropyridine, 
\( \text{C}_3\text{H}_7(\text{NO}_2)\text{C}_3\text{H}_7\text{N} \); mw 152.15, N18.41%; yell oil, bp 56-8\(^\circ\), (0.25 mm Hg), n\(D\) 1.5305 at 16\(^\circ\). Prepd by converting 3-ethylpyridine to the N-oxide, nitrating this at 50-95\(^\circ\) with mixed acid to give the N-oxide intermediate (yell ndls, mp 68-9\(^\circ\)), and further treatment with PCl\(_5\) in chlf at 0-10\(^\circ\).


4-Ethylpyridine, \( \text{C}_4\text{H}_6\text{C}_3\text{H}_7\text{N} \); mw 107.15, N13.07%; liquid, sp gr 0.936 at 20\(^\circ\) (Lange); 0.9460 at 20\(^\circ\) (Ref 3), bp 160\(^\circ\), n\(D\) 1.5018 at 20\(^\circ\), v sl sol in w; sol in alc & eth. Can be prepd by heating N-ethyl-pyridinium iodide in a tube at 300\(^\circ\). It is dangerous when heated to decompose as toxic fumes of nitrogen oxide are emitted; can react with oxidizing materials (Ref 4)


4-(1,1-Dinitroethyl)-pyridine,
\( (\text{NO}_2)_2\text{C}_3\text{H}_4=\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{NO}_2)_2\) ; mw 197.15, N21.32%; crysts, mp 55-7\(^\circ\). Prepd by treating with 25% H\(_2\)O\(_2\) and 93% HNO\(_3\) a mixture of methylol-4-ethyl pyridines at 100\(^\circ\). There is a picrate salt; mp 137\(^\circ\) 

Refs: 1) Beil, not found 2)M.V.Rubtsov et al, ZhurObshchKhKim 25, 2453-7 (1955) & CA 50, 9401 (1956)

Ethylquinolone and Derivatives

N-Ethyl-2-quinolone or N-Ethyl-a-carbostyril,
\( \text{C}_6\text{H}_5\text{CH}=\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 173.22, N8-09%; ndls (pet eth), mp 53-5\(^\circ\), bp 316-18\(^\circ\), sol in usual organics. Prepd by refluxing a-carbostyril with ethyl iodide and sodium alcoholate


N-Ethyl-5-nitro-2-quinolone,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 218.22, N12.84%; crysts (alc), mp 135\(^\circ\), sol in alc, benz & hot w. Prepd by treating 5-nitroquinoline ethylidolate with potassium ferricyanide


N-Ethyl-6-nitro-2-quinolone,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 218.22, N12.84%; yell ndls (alc), mp 183\(^\circ\). Prepd by nitrating the parent, heating ethylidolate with sodium 6-nitro-2-quinololate, or by the potassium ferricyanide oxidation as with the 5-nitro compd


N-Ethyl-6-nitro-2-quinoloniun Nitrato,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 281.23, N14.94%; yell ndls, mp 183\(^\circ\). Prepd from the parent and nitric acid. Loses nitric acid in w or on standing in air


N-Ethyl-7-nitro-2-quinolone,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 218.22, N14.94%; ndls (alc), mp 168-9\(^\circ\). Prepd by oxidation of 7-nitroquinoline ethylidolate with alkaline potassium ferricyanide


N-Ethyl-8-nitro-2-quinolone,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 218.22, N14.94%; yell tufts (methanol, benz/per eth), mp 96\(^\circ\), sol in benz. Prepd by heating sodium-8-nitro-quinololate with ethylidolate at 150\(^\circ\)


N-Ethyl-5, x-dinitro-2-quinolone,
\( (\text{NO}_2)_2\text{C}_3\text{H}_7\text{CH}-\text{CH}-\text{C}(\text{OH})-(\text{C}_2\text{H}_5) \); mw 263.22, N15.97%; spears (alc), mp 197\(^\circ\) (dec). Prepd from the 5-nitro compd by treatment with fuming HNO\(_3\)

**N-Ethyl-6-x-dinitro-2-quinoline,**
(NO₂)₃C₈H₇-CH=CH-C(O)-N(C₂H₅); mw 263.22, N15.97%; yel plates (tol), mp 216°, subl, expl at higher temp; sol in acidic and neutral liqs. Prepd from the 6-nitro compd by treatment with concd HNO₃

**N-Ethyl-5-x,x-trinitro-2-quinoline,**
(NO₂)₃C₈H₇-CH=CH-C(O)-N(C₂H₅); mw 308.22, N18.18%; crysts (tol) contain tol, mp 222° (dec.). Prepd by refluxing the 5-nitro compd with fuming HNO₃

**N-Ethyl-6-x,x-trinitro-2-quinoline,**
(NO₂)₃C₈H₇-CH=CH-C(O)-N(C₂H₅); mw 308.22, N18.18%; yel crysts (tol), mp 224°, sol in warm NaOH; diff sol in hot alc. Prepd from the parent of the 6-nitro compd by vigorous nitration

**Ethylsalicylate and Derivatives**

**Ethylsalicylate,** HO.C₈H₅-COO.C₂H₅; mw 166.18, colorless liq, sp gr 1.13 at 25/25°, bp 234°, 139° (50 mm Hg), 102° (9 mm Hg), fr p 1.3°, nD 1.525 at 14.4°, sol in eth & alc; insol in water. Prepd by esterification of salicylic acid with alc HCl
It is used medicinally as an antiseptic, and as a solvent for NC

**4-Azidoethylsalicylate,**
N₃(HO)C₈H₅-COO.C₂H₅; mw 207.19, N20.28%; mp 50-1° (dec). Prepd by diazotization of 4-aminoethylsalicylate followed by reaction with hydrazine

**3-Nitroethylysalicylate,**
O₂N(OH)C₈H₅-COO.C₂H₅; mw 211.18; N6.63%; plates or ndls (alc), mp 44°, sol in cold w and alc. Prepd by esterification of 3-nitrosalicylic acid with refluxing alc and concd H₂SO₄

**4-Nitroethylysalicylate,**
O₂N(OH)C₈H₅-COO.C₂H₅; mw 211.28; N6.63%; ndls (alc), mp 87°, sol in eth & benz. Prepd by esterification of 4-nitro salicylic acid by warming with alc H₂SO₄
Refs: 1)Beil 10, (51) & [67] 2)W.Borsche, Ann 390, 18 (1912)

**5-Nitroethylsalicylate,**
O₂N(OH)C₈H₅-COO.C₂H₅; mw 211.18, N6.63%; ndl (alc), mp 92-93°, sol in alc & eth; insol w. Prepd by esterification of 5-nitro salicylic acid with alc H₂SO₄

**3,5-Dinitroethylsalicylate,**
(O₂N)₂(OH)C₈H₅-COO.C₂H₅; mw 256.18, N10.94%; plates (alc), mp 99-100°, sol in hot alc. Prepd by mixed acid nitration of the ester

**Trinitroethyl Salicylate,**
HO.C₈H₅-COO.C₈H₅-C(NO₂)₃; mw 301.17, N13.95%; OB to CO₂ 66.7%, crysts, sp gr 1.60, mp 71°. Can be prepd by the reaction of the acid chloride of salicylic acid with Tri-nitroethanol (Ref 2). Its sensitivity to impact approaches that of TNT. It can be used as a castable medium for expl compds
Trinitroethyl-3,5-dinitro-salicylate,
HOC6H2(NO2)2-COO.CH3.C(NO2)2; mw 391.17,
N17.65%, OB to CO2 30.8%, crysts, sp gr 1.64,
mp 124°; ignites at 219°. Can be prepd by the
nitration of trinitro ethylsalicylate with mix-
ed acid (Ref 2). Its impact sensitivity is
about that of Comp A
Refs: 1)Beil, not found 2)Hercules Powder
Co, Progress Rept March 1949, High Expels,
Task A, Contract NOrd 9925 3)W.W.Sager
& D.V.Sickman, NAVORD Rept 483 (1952),
p 14

Ethyl Silicate or Tetramethyl Orthosilicate,
Si(OSiMe4); mw 208.30; col, flammable liq
with faint odor; sp gr 0.9356 at 20/20°, ft p
-82.5° (Lange), -77° (Ref 3); bp 169.8°
(Lange), 168.1° (Ref 3); fl p 125°F, vapor
press 1.0 mm at 20°, viscosity 0.0179 poises
at 20°, sol in alc; hydrolyzed by W. Can be
prepd from silicon tetrachloride and alc.
Used as a bonding agent and for many other
purposes indicated in Ref 3
Refs: 1)Beil 1, 334 2)M.Ebelmen, Ann
57, 334 (1846) 3)CondChemDict (1961),
476-R & 477-L; 8th edict (1971), 374-L
4) Sax, 3rd edict (1968), 762

Ethyl Stearate and Derivatives
Ethyl Stearate, C17H35COO.CH2.CH3; mw
146.14; col crysts, sp gr 0.848 at 36°, mp
33.8° (31.1°), bp 199-201° at 10 mm; insol in
w; sol in alc & eth. Can be prepd by ester-
ification in 3% alc.HCl
Refs: 1)Beil 2, 379, (172), [352] & [1013]
2)Holtzmann, ArchPharm 236, 440 (1898)

Trinitroethyl Stearate,
C17H35COO.CH2.C(NO2)2; mw 447.53,
N9.39%; crysts, sp gr 1.20, mp 46°. Can be
prepd by interaction of acid chloride of stea-
ic acid with Trinitroethanol. It is an expl
insensitive to impact above 160 cm on ERL
machine and unstable to heat. The vacuum
stability test 100° gave over 30 ml of gas per
1.0g in 48 hours
Refs: 1)Beil, not found 2)W.F.Sager &
D.V.Sickman, NAVORD Rept 483 (1952), Res
& Devel in New Chemical High Explos, p 35

Ethyl-substituted Acid Amides, N-Trinitro
Derivatives. Their prep was described by
Th.Quadflieg, DAS 1102135, Kl 12-0-16 and
abstracted in Explosivstoffe 1962, 81-2

Ethylsuccinic Acid and Derivatives
Ethylsuccinic Acid,
HOOC.CH(C2H5).CH2.COOH; mw 146.14;
col crysts, mp 98°, sol in w, alc or eth.
Can be prepd by sodium amalgam reduction
of CH3.CH=CH(CO2H).CH2.CO2H in weak
acid
Refs: 1) Beil 2, 660, (279) & [584] 2)
R.Fittig & I.Frankel, Ann 255, 41 (1889)

Ethylsuccinyl Diazoide,
N2OC.CH(C2H5).CH2.CON; mw 196.17,
N42.83%; brownish yel oil; mp-puffs off on
heating. Was prepd by Curtius by treating
ethylsuccinyl diarydrazide with HNO2 in eth
Refs: 1) Beil, not found 2)Th.Curtius,
JPraktChem 125, 82 (1930) & CA 24, 3231
(1930)

Ethylsuccinyl Hydrazide,
H2N.NH.OC.CH(C2H5).CH2.CONH.NH2; mw
174.20, N15.72%; ndls (alc), mp 163°, sol in
alc & w. Prepd from the diethyl ester of the
parent and hydrazine in refluxing alc. Forms
a Dipicrate salt, yel ndls, mp 190°
Refs: 1)Beil, not found 2)Th.Curtius,
JPraktChem 125, 79 (1930) & CA 24, 3231 (1930)

Ethylsulphhydrate. See Ethylmercaptan in this
vol

Ethylsulfuric Acid (Ethyl Hydrogen Sulfate),
C2H5.HSO4.OH, mw 126.13; col oily liq, sp gr
1.318 at 17°, bp 280° with decomp; sol in w,
alc or eth; decomp by hot w or hot alc. Can
be prepd by the action of sulfuric acid on
ethanol. Used in medicine, org preps and as a
precipitant for casein
Refs: 1) Beil 1, 325 2)CondChemDict (1961),
477-L; 8th edict (1971), 374-R 3) Sax, 3rd
edict (1968), 763-L
ethyltetrazinedicarboxylic acid and derivatives

HOOC.C
\[\text{N} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{COO.C}_2\text{H}_5\]

mw 198.14, N 28.28%. This compound is not found in the open literature
refs: 1) Beil, not found 2) CA, not found

ethyltetrazinedicarboxylic acid (tetrazin-dicarbonsäure-äthylesterazid, in ger),

\[\text{N} \quad \text{O.C.} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{COO.C}_2\text{H}_5\]

mw 223.15, N 43.94%, violet-red plates, mp explodes on heating, sol in acet & chf. Prepd from the corresponding hydrazide and HNO₂ in cold chf
refs: 1) Beil 26, 571 2) Th. Curtius & E. Rimele, Ber 41, 3112-13 (1908) & CA 3, 65 (1909)

ethyltetrazole and derivatives

ethyltetrazoles. Their parent compds known as tetrazoles can be either

1H(or a)-tetrazole, \(\text{NH} \quad \text{N} \quad \text{N} \quad \text{N} \quad \text{CH}, \) or

2H(or β)-tetrazole, \(\text{CH} \quad \text{N} \quad \text{NH} \quad \text{N} \quad \text{N} \)

and ethyl group can be placed in position 1 of 1H-tetrazole, position 2 of 2H-tetrazole and position 5 of 1H- or 2H-tetrazoles (see vol 1 of encyclop v)

the following ethyltetrazoles, C₄H₄N₄, mw 98.11, N 57.12, are described in the literature:

1-ethyltetrazole, \(\text{N} \quad (\text{C}_2\text{H}_3) \quad \text{N} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{NH}, \) or

mw 98.11, N 57.12%; liq, bp 155-6° (14mm Hg), sol in alc, eth, benz & w. Prepd by heating hydrazoic acid and ethylisocyanide in eth
refs: 1) Beil 26, (108) 2) E. Oliveri-Mandalà & B. Alagna, Gazz 40 II, 442 (1910)

2-ethyltetrazole, \(\text{CH} \quad \text{N} \quad \text{N} \quad (\text{C}_2\text{H}_3) \quad \text{N} \quad \text{N} \)

mw 98.11, N 57.12%; liq, bp 152-5°, 70-1° (35mm Hg). Prepd by heating 2-ethyltetrazole-5-carboxylic acid at 130-40°
refs: 1) Beil 26, 108 2) E. Oliveri-Mandalà & T. Passalacqua, Gazz 41 II, 435 (1911)

ethyltetrazolylcarbamate, \(\text{N} \quad \text{N} \quad \text{CH} \quad \text{N} \quad \text{C} \quad \text{NHCOOC}_2\text{H}_5\)

mw 157.14, N 44.57%; solid (from 95% alc), mp dec 25-56°. It was prepd by refluxing 5-aminotetrazole (0.1 mol) & ethyl chloroformate (0.2 mol) for 4 hrs. This compd can be nitrated, followed by hydrolysis of the nitrocarbamate to convert it to nitratinetetrazole. This compd is sl sol in hot w & alc; v sl sol in eth. It forms a silver salt
refs: 1) Beil 26, (244) 2) R. Stollé, Ber 62, 1121 (1929) 3) ADL, synthesis he's, 3rd rept (1953), 305

ethylytaryl. See N-Ethyl-(2,4,6-trinitrophenyl)-nitroguanidine under N-ETHYLPHENYLMINES AND DERIVATIVES in this vol

ethyltoluenes and derivatives

ethyltoluenes or ethylmethylbenzenes,
C₄H₄.C₃H₄.C₆H₃; mw 120.19. Three isomers are known: ortho-, meta- and para-. Their preparations and properties are given in refs

3-nitro-2-ethyltoluene,
C₆H₄(CH₃XC₆H₃)NO₂; mw 165.19, N 8.48%; liq, bp 75-9° (1.2mm Hg). Prepd by mixed acid nitration of the parent at 0-5°
refs: 1) Beil, not found 2) M. Dolinsky et al, J Assoc Offic Agr Chemists 42, 709-20 (1959) & CA 54, 4268 (1960) (also infrared spectrum)
4-Nitro-2-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
cryst, mp 23°, bp 271°, 130–31° (10mm Hg),
89–92° (1.2mm Hg). Prepd from 5-aminoo-
2-ethyltoluene by nitration of the acet-
anilide (yel, mp 103°), return to the free
amine (om, mp 90°), and finally deamina-
tion with HNO₂
Refs: 1) Beil, not found  2) G.T. Morgan
CA 28, 4396–7 (1934). See Ref 2 of pre-
ceding entry for infrared spectrum

5-Nitro-2-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 89–92° (1.2mm Hg). Prepd by mixed
acid nitration of the parent at 0–5°
Refs: 1) Beil, not found  2) M. Dolinsky
et al, JAssoCOfficAgChems 42, 709–20
(1959) & CA 54, 4268 (1960) (Also infrared
spectrum)

6-Nitro-2-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 78–80° (1.2mm Hg). Prepd by mixed
acid nitration of the parent at 0–5°
Refs: 1) Beil, not found  2) M. Dolinsky
et al, JAssoCOfficAgChems 42, 709–20
(1959) & CA 54, 4268 (1960) (Also infrared
spectrum)

2-Nitro-3-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 72–6° (1mm Hg). Prepd by mixed acid
nitration of the parent at 0–5°
Refs: 1) Beil, not found  2) M. Dolinsky
et al, JAssoCOfficAgChems 42, 709–20
(1959) & CA 54, 4268 (1960) (Also infrared
spectrum)

4-Nitro-3-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 253–63°, 70–71° (0.7mm Hg). Prepd
by mixed acid nitration of the 6-acetanilido-
3-ethyltoluene (mp 143°), return to the free
amine (gold, mp 74°), and finally deamina-
tion with HNO₂
Refs: 1) Beil, not found  2) G.T. Morgan
CA 28, 4396–7 (1934). See Ref 2 of pre-
ceding entry for infrared spectrum

5-Nitro-3-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
yel liq, bp 263–64°. Prepd by nitration in
acetic acid of the 6-acetanilido-3-ethyl-
toluene (yel, mp 142°), return to the free
amine (red, mp 64°), and finally deamina-
tion with HNO₂
Refs: 1) Beil, not found  2) G.T. Morgan &
CA 28, 4396–7 (1934)

6-Nitro-3-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 245° (dec), 70–71° (0.5mm Hg). Prepd
by nitration in acetic acid of the parent, cold
Refs: 1) Beil 5, [310]  2) A. Mailhe, CR
173, 160–62 (1921) & CA 15, 3985 (1921) (CA
has incorrect formula); for infrared spectrum
see Ref 2 for 2-nitro-3-ethyltoluene deriv

2-Nitro-4-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 247–49°, 73–76° (1mm Hg). Prepd
by mixed acid nitration of the parent
Refs: 1) Beil, not found  2) O.L. Brady &
28, 1993 (1934); for infrared spectrum see
Ref 2 for 2-nitro-3-ethyltoluene above

3-Nitro-4-ethyltoluene,
C₆H₄(CH₃)(C₆H₄)NO₂; mw 165.19, N 8.48%;
liq, bp 113–20° (10mm Hg), 69–73° (1mm Hg).
Prepd by hydrazine reduction at 200° of
3-nitro-4-ethylbenzaldehyde
Refs: 1) Beil, not found  2) I.J. Rinkes,
Rec 64, 205–13 (1945) & CA 40, 4034 (1946);
for infrared spectrum see Ref 2 for 2-nitro-
3-ethyltoluene above

2-(1-nitroethyl) toluene,
C₆H₄(CH₃)(CH(NO₂)CH₃; mw 165.19, N 8.48%;
liq, bp 86–89° (1mm Hg), nD 1.5208 at 20°.
Prepd by reaction of the corresponding bromo
compd with NaN₃ at –18° in dimethylformi-
mide containing urea and phosphogluconol
Refs: 1) Beil, not found  2) M. Fukuyama
et al, JACS 92(15), 4697 (1970) & CA 73,
65645 (1970)

4-(1-nitromethyl) toluene,
C₆H₄(CH₃)(CH(NO₂)CH₃; mw 165.19, N 8.48%;
liq, bp 78° (0.5mm Hg), nD 1.5288 at 20°.
Prepd in the same way as the preceding
entry, from the corresponding parent
Refs: See preceding entry
x,x-Dinitro-3-ethyltoluene,
C₆H₃(CH₃)(C₆H₅(NO₂)₂); mw 210.19, N 13.33%; liq, steam distils. Prep'd by nitration of the parent in the cold; not further characterized or identified
Refs: 1) Beil 5, 397 2) E. Bartow & A.W. Sellards, JACS 27, 372 (1905)

x,x-Dinitro-4-ethyltoluene,
C₆H₂(CH₃)(C₆H₅(NO₂)₂); mw 210.19, N 13.33%; plates (alc), mp 51-52°, sol in boiling alc. Prep'd from the parent in cold fuming nitric acid; a non-cryst oil, dinitro derivative is also obtained. Possibly the 2,3-dinitro
Refs: 1) Beil 5, 399 2) P. Jannasch & A. Dieckmann, Ber 7, 1514 (1874)

2,3-Dinitro-4-ethyltoluene,
C₆H₂(CH₃)(C₆H₅(NO₂)₂); mw 210.19, N 13.33%; crystals, mp 51.9°. Prep'd by mixed acid nitration of the parent
Refs: 1) Beil, not found (but see preceding entry) 2) O.L. Brady & J.N.E. Day, JCh Soc 1934, 114-21 & CA 28, 1993 (1934)

2,6-Dinitro-4-ethyltoluene,
C₆H₂(CH₃)(C₆H₅(NO₂)₂); mw 210.19, N 13.33%; crystals, mp 60°(62-5°). Prep'd by nitrous acid deamination of the 3-amino compd (red nlds (MeOH), mp 145°)

3,5-Dinitro-4-ethyltoluene,
C₆H₃(CH₃)(C₆H₅(NO₂)₂); mw 210.19, N 13.33%; yel crystals, mp 48.5°. Prep'd by mixed acid nitration at ~10° of 2-acetanilidino-4-ethyltoluene, reum to the free amine (yellow plates (benz), mp 186°), and nitrous acid deamination
Refs: 1) Beil, not found 2) L.J. Rinkes, Rec 64, 205-13 (1945) & CA 40, 4034 (1946)

2,4,6-Trinitro-3-ethyltoluene,
C₆H(CH₃)(C₆H₅(NO₂)₂); mw 255.19, N 16.47%; plates (alc), mp 86°(90°). Prep'd by treating an intermediate dinitration product of the parent with fuming nitric acid and conc sulfuric acid
Refs: 1) Beil 5, 397 & [310] 2) E. Bartow & A.W. Sellards, JACS 27, 372 (1905)

2,3,5-Trinitro-4-ethyltoluene,
C₆H(CH₃)(C₆H₅(NO₂)₃); mw 255.19, N 16.47%; crystals, mp 82°. Prep'd by mixed acid nitration of the 3,5-dinitro compd (See above)
Refs: See 3,5-dinitro-4-ethyltoluene above

2,3,6-Trinitro-4-ethyltoluene,
C₆H(CH₃)(C₆H₅(NO₂)₃); mw 255.19, N 16.47%; prisms (alc), mp 93-94°. Prep'd by warming the parent in mixed acid
Refs: 1) Beil 5, 399 2) E. Glinzer & R. Fittig, Ann 136, 314 (1865)

Ethyltoluene Sulfonate and Derivatives

Ethyl-p-toluene Sulfonate, C₆H₅C₆H₄·SO₃·C₂H₅; mw 200.26; toxic unstable crystals (from alc), sp gr 1.166 at 48-49°, mp 33-34°, bp 221.5°; insol in w; sol in alc, eth & most org solvents. It can be prep'd from the sulfonyl chloride and alc Used as plasticizer for cellulose acetate and as an ethylating agent (Ref 3)
4) Sax, 3rd edit (1968), 763-R

Azido Ethyl-p-toluene Sulfonate, mw 241.27, N 17.41%. No refs to any compd fitting this name are found in the open literature.
Refs: 1) Beil, not found 2) CA, not found

Nitro Ethyl-p-toluene Sulfonate, mw 245.26, N 5.71%
No refs to any para compd are found in the open literature. There is a 4-nitro-ethyl-o-toluenesulfonate, mp 85-86°, prep'd by esterification of the free acid obtained by fuming nitric acid oxidation of bis(4-nitro-2-methylphenyl)dissulfide (Ref 2)
Refs: 1) Beil, not found 2) P. Pfeiffer & H. Jäger, Ber 75B, 1885-90 (1942) & CA 38, 1218 (1944)

3,5-Dinitro-ethyl-p-toluene Sulfonate or 3,5-Dinitro-4-methyl-ethylbenzene Sulfonate, (NO₂)₂C₂H₅(CH₃)·SO₃·C₂H₅; mw 290.26, N 9.65%; crystals, mp 82-84° (tol/hex). Prep'd from the sulfonyl chloride and sodium eth oxide. The ortho-isomer is also mentioned in the same Ref, mp 87-90°, prep'd in the same manner

2,2,2-Trinitroethyl-p-toluene Sulfonate,
CH₃C₆H₄SO₂CH₂CH₂C(NO₂)₃; mw 335.26,
N 12.50%, OB to CO₂ -74.0%, crystals (benz),
mp 136.5-137.5°. Prepd by heating p-toluene-
sulfonyl chloride with trinitroethanol and a
trace of pyridine
Refs: 1) Beil, not found 2) F. G. Borgardt
et al, JOC 35(12), 4238 (1970) & CA 74,
22390 (1971)

N-Ethyl-p-toluenesulfonamide and Derivatives

N-Ethyl-p-toluenesulfonamide,
CH₃C₆H₄SO₂NH.CH₂CH₂N₃; mw 240.29,
N 23.32%, ndls (petr eth), mp 64° (63-64°).
Prepd from the sulfonyl chloride and ethylamine in alkaline
solution

N-(2-azidoethyl)-p-toluenesulfonamide,
CH₃C₆H₄SO₂NH.CH₂CH₂NH₃; mw 244.27,
N 11.47%, yel prisms (alc), mp 87°.
Prepd from the sulfonyl chloride and ethylamine
Refs: 1) Beil 11, 111 2) F.D. Chattaway,
J Chem Soc 87, 160 (1905)

3-Nitro-N-ethyl-p-toluenesulfonamide or
3-Nitro-4-methyl-N-ethyl-benzensulfonamide,
NO₂C₆H₃SO₂NH.CH₂CH₂N₃; mw 244.27,
N 11.47%, plates (eth), mp 69°, sp gr 1.450.
No prep is given in the Ref, possibly by
reacting the sulfonyl chloride with ethyl-
nitramine
Refs: 1) Beil 11, [67] 2) F.M. Jaeger,
Proc Acad Sci Amsterdam 23, 347-62 (1920) &
CA 15, 689 (1921)
4-Nitro-3-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 180.20, N 15.54%;
yel-red ndls (dil alc), mp 60°. Prepd from 4-
-nitro-3-ethoxy-toluene by heating with alc
ammonia at 165–70°
Refs: 1) Beil 12, 876 2) O. Fischer &
M. Rigaud, Ber 34, 4207 (1901)

2-Nitro-4-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 180.20, N 15.54%;
red prisms or yel ndls, mp 47–48° (50°), sol
in alc & eth. Prepd by nitration p-ethyltolui-
dine with mixed acid
Refs: 1) Beil 12, 997 2) E. Noetling & T.
Stricker, Ber 19, 549 (1886)

2,4-Dinitro-3-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 225.20,
N 18.66%; yel ndls (alc), mp 68–69°, sol in
usual organics. Prepd by warming 2,3,4-
trinitrotoluene with benzylidenethyamine in alc
Refs: 1) Beil 12, [479] 2) M. Giua & R.
Petronio, JPCh [2] 110, 306 (1925) & CA 20,
173 (1926)

4,6-Dinitro-3-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 225.20,
N 18.66%; yel ndls (alc), mp 125–126°, sol in
usual organics. Prepd by warming 2,3,4-
trinitrotoluene with benzylidenethyamine in alc
Refs: 1) Beil 12, [480] 2) M. Giua & R.
Petronio, JPCh [2] 110, 306 (1925) & CA 20,
173 (1926)

3,5-Dinitro-4-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 225.20,
N 18.66%; om-yel ndls (alc), mp 126–126.5°,
sol in benz. Prepd by further ni tration of the
3-nitro compd in nitric acid below 30°
Refs: 1) Beil 12, 1010 & (443) 2) L.
Gattemann, Ber 18, 1485 (1885)

2,4,6-Trinitro-3-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 270.20,
N 20.73%; yel crys ts, mp 98°. Prepd from
ethyamine and 2,4,6-trinitro-3-methoxy-
toluene in alc
Refs: 1) Beil 12, 879 2) J.-J. Blanksma,
Rec 21, 333 (1902)

N,3,5-Trinitro-2-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 270.20,
N 20.73%; yel crys ts (alc), mp 71–72°. Prepd
by refluxing diethyl-o-toluidine with fuming
nitric acid
Refs: 1) Beil 12, 852 2) P. van Rombrugh,
Rec 3, 403 (1884)

N,3,5-Trinitro-4-(ethylamino)toluene,
\[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 270.20,
N 20.73%; yel ndls (alc), mp 116°. Prepd by
refluxing diethyl-p-toluidine with sp gr 1.48–
1.52 nitric acid
Refs: 1) Beil 12, 1012 2) P. van Rombrugh,
Rec 3, 409 (1884)

Tetranitroethyltoluidine, 3-(N-Ethyl-N-nitro)-
2,4,6-trinitrotoluolene or Trinitrotetroethyl-
aminotoluene, \[ \text{C}_8\text{H}_8\text{N}_3\text{O}_2\text{N}_2 \] mw 315.20,
N 22.22%, OB to CO₂ –73.7%;
crys ts, mp 79°. Prepd by treating 2,4,6-
trinitro-3-(ethylamino)toluene with sp gr
1.52 nitric acid
Refs: 1) Beil 12, 880 2) J.-J. Blanksma,
Rec 21, 333 (1902)

Ethyltriazole and Derivatives
Ethyltriazoles are triazoles with an ethyl
group replacing one of the H's. Our way of
writing the formulas of triazoles is given in
Vol 1 of Encycl. p VI. Using our formulas,
the compd 4-Ethyl-1,2,4-triazole will be written
as:
\[ \text{HC} = \text{N} – \text{N} \]
\[ \text{C}_2\text{H}_3\text{N} – \text{CH} \]
\[ \text{C}_2\text{H}_3\text{N} – \text{C(NO}_2\text{)} \]
\[ \text{CH}_3\text{N} – \text{C(NO}_2\text{)} \]
mw 97.12, N 43.25%; oil, sol in alc & w.
Prepd by treating the 3-mercapto deriv with
hydrogen peroxide
Refs: 1) Beil 26, 14 2) M. Freund & H.P.
Schwarz, Ber 29, 2488 (1896)

4-Ethyl-3-nitro-1,2,4-triazole,
\[ \text{HC} = \text{N} – \text{N} \]
\[ \text{C}_2\text{H}_3\text{N} – \text{C(NO}_2\text{)} \]
mw 142.12, N 39.43%. There is no open litera-
ture ref to this compd. The 5-ethyl-3-nitro
compd is known, however, mp 121°. Prepd by
adding the 5-ethyl-3-amino compd in 10% sul-
furic acid to 10% NaN₂ at 45°
Refs: 1) Beil, not found 2) L.L. Bagal er
& CA 72, 111383 (1970)
4-(1)-Ethyl-3,5-dinitro-1,2,4-triazole,
\[(O_2N)C\equiv N\equiv N\]
\[(C_2H_3)\equiv N\equiv C(NO_2)\]
mw 187.12, N 37.43%, OB to CO₂ 55.6%; solid, mp 79°. The position of ethyl group is uncertain. It was prepared by interaction of the silver salt of Dinitrotiazole and ethyl iodide. It is an exp insensitive to impact above 160 cm with ERL machine, 2.5 kg wt.

4-(2-Nitroethyl)-3,5-dinitro-1,2,4-triazole,
\[(O_2N)C\equiv N\equiv N\]
\[(C_2H_5)\equiv CH\equiv CH\equiv N\equiv C(NO_2)\]
mw 232.12, N 36.21%, OB to CO₂ 27.5%; crysts, sp gr 1.76, mp 147°, ignition point 274°. Prepd by treating Dinitrotiazole with Nitroethylene at RT. It is exxp with impact sensitivity comparable to that of Tetryl.
Refs: 1) Beil, not found 2) Univ of Louisville, Kentucky, Quarterly Progress Rept No 7 (1951), Contract NoRD 10804 3) W.F. Sager & D.V. Sickman, NAVORD Rept 483 (1952), p 7 4) D.V. Sickman, USP 2987520 (1961) & CA 56, 4776 (1962)

**Ethyltrichloro silane**, C₂H₅·SiCl₃; mw 163.51; colorless, flammable liquid; sp gr 1.236 at 25/25°, fp -105.6°, bp 99.5°, nD₂ 1.4257 at 25°, fl p (Cleveland open cup) 57°C; readily hydrolyzed by moisture with formation of HCl. It can be prepd by reaction of ethylene and trichlorosilane in presence of a peroxide catalyst. It is used as an intermediate for silicones. This compd may form expl mixts with air. It is also highly toxic.

**Ethyltrimethylene glycol and Derivatives**
\(\beta\)-Ethyltrimethylene glycol (2-methylolebutanol-1), in Gei, C₂H₅·CH₂·(CH₂OH)₂; mw 104.15; liq, sp gr 0.997 at 20°, bp 86-87° (0.5mm Hg), nD₂ 1.4480 at 20°. Prepd by reducing ethyl dieethylmalonate with copper chromite in methanol.
Refs: 1) Beil, not found 2) R. Mozingo & K. Fokkers, JACS 70, 227-239 (1948) & CA 42, 2233 (1948)

**\(\beta\)-Nitro-\(\beta\)-ethyl-trimethylene glycol**, C₂H₅·C(NO₂)·(CH₂OH)₂; mw 149.15, N 9.39%; nds (w), mp 57-58°, sol in w, alc & eth. Prepd by reacting formaldehyde with 2-nitrobutanol-1 or with nitropropane, and potassium carbonate. Used for making polyesters.
Refs: 1) Beil 1, 483 2) J. Pauwels, Chem Zentr 1898 I, 193

**Note**: There is no open literature reference to mono- or dinitrate derivatives of the parent or the nitro compd, but the nitro-dinitrate compd may have been prepd (mw 237.13, N 17.72%, OB to CO₂ 37.1%), presumably by nitration of the nitro compd. Possibly the lack of interest is due to the attention paid to pentaoxythiol and its nitrated derivs which have similar empirical formulas.

**Ethyl-trimethylolmethane and Derivatives**
Ethyl-trimethylolmethane or 2-Ethyl-2-Hydroxymethyl-1,3-propanediol,
C₅H₁₂·C(CH₂OH)₃; mw 134.18; white crysts, mp 57-59°, bp 160°(5mm Hg), hyg; sol in w, alc & acct. Prepd by reacting butylaldehyde and formaldehyde in the presence of alkali. Used to make polyurethane resins.

Azido Ethyltrimethylolmethane,
C₅H₁₄·N₃·C(CH₂OH)₃, mw 175.19. There is no reference to this compd in the open literature.
Refs: 1) Beil, not found 2) CA, not found

**Ethyltrimethylolmethane Nitrate**, C₅H₁₂·C(CH₂OH)₂·CH₂ONO₂; mw 179.18. There is no reference to this compd in the open literature.
Refs: 1) Beil, not found 2) CA, not found

**Ethyltrimethylolmethane Dinitrate**, C₅H₁₂·C(CH₂ONO₂)₂·CH₂OH; mw 224.18, N
Ethyltrimethylmethane Trinitrate,

C₆H₁₅(CH₃NO₃)₂; mw 269.18, N 15.61%,
OB to CO₂ -50.6%; crystals, mp 51°, expl 220°,
sp gr 1.48. Prepd by nitration of the parent
(Ref 3). Expl props are similar to those of
Tetryl

Detonation velocity – 7040 m/sec in 30mm dia
Heat of combustion at Cᵥ – 829 kcal/m
Impact sensitivity – 3.6kg.m (4kg.m for more
crystalline material)

Trael point value – 115.5°

Refs: 1) Beil, not found 2) H. Henkin &
R. McGill, IndEngChem 44, 1391-5 (1952) &
CA 46, 8857 (1952) (Expn wmp, also other props)
3) L. Médaard, MP 35, 113-15 (1953)
& CA 49, 6082 (1955) 4) Ibid, 36, 87-92
(1954) & CA 50, 6793 (1956)

Ethyleurea and Derivatives

Ethyleurea, C₄H₉.NH.CO.NH₂; mw 88.11, ndls
(alc/eth), sp gr 1.213 at 18°, mp 92°, flash p
>200°F; v sol in w & alc; insol in eth. Prepd
from ethylisocyanate and ammonia

Refs: 1) Beil 4, 115, (353) & [607] 2) A.
Wurtz, CR 27, 241 (1848) 3) Sax, 3rd edit
(1968), 764-L

Azidoethyleurea, N₃.CH₂.CH₂.NH.CO.NH₂;
mw 129.12, N 54.29%; scales (benz), mp 59°,
sol in alc & w; insol in petr eth. Prepd from
2-azidoethyl-ammonium chloride & potassium
cyanate in w

Refs: 1) Beil 4, (360) 2) M.O. Forster &

N-Nitro-N'-ethyleurea, C₄H₉.NH.CO.NH.NO₂;
mw 133.11, N 31.60%; hygr ndls (eth), mp
133-34°, sol in eth. Prepd by reacting the parent
with ethyl nitrate in concd sulfuric
acid at -5°

Refs: 1) Beil 4, 117 2) J. Thiele & A.
Lachman, Ann 288, 285 (1895) 3) T.L.
Davis & N.D. Constan, JACS 58, 1800-3
(1936) & CA 30, 7543 (1936) (Prepa)

N-Trinitroethyleurea, (O₃N)₆.C.CH₂.NH.CO.NH₂;
mw 223.10, N 31.40%, OB to CO₂ -10.8%;
crystals, mp 175-76°. It was assumed to be
the product obtd on treating an aq soln of
urea with Trinitroethanol and 1 drop of HCl.
It bummed rapidly and could be detonated
with some difficulty by impact

Refs: 1) Beil, not found  2) USRubberCo,
QuarterlyProgresssRept No 7 (1949), 16
3) Ditto, Rept No 8 (1949), p 25 (Description
of Pilot Plant Process)

Ethylethane and Derivatives

Ethylethane or Ethyl-N-ethyl Carbamate,
C₄H₉.NH.CO.C₂H₅; mw 117.15, colorless
liq, sp gr 0.981 at 20/4°, bp 175°, nD 1.4219
at 20°, sol in w; decomp by hot alc. It can
be prepd by heating ethylisocyanate with
alc at 100°

Refs: 1) Beil 4, 114, (353) & [607] 2) A.
Wurtz, JahresbForschChem 1854, 565

N-Nitro-ethylcarbamate, C₄H₉.N(NO₂).CO₂.C₂H₅;
mw 162.15, N 17.28%; liq, sp gr 1.163 at
20/20°, bp 107° (31mm Hg), nD 1.4432 at 20°.
Prepd from the parent by nitration with fuming
nitric acid and A₅O₂ at 0-25°

Refs: 1) Beil, not found  2) H.M. Curry &
J.P. Mason, JACS 73, 5043-46 (1951) & CA
47, 497 (1953)

Dinitroethylurethane, C₄H₉.N₂O₂; mw 207.15,
N 20.30%. There is no reference to this compd
in the open literature

Refs: 1) Beil, not found  2) CA, not found

Trinitroethylurethane,

C₄H₉.N.CO₂.C₂.H₂(C(NO₂)₂; mw 252.15, N
22.22%, OB to CO₂ -38.1%; yeil oil. Prepd by
either reacting nitroform with HO.C₂H₂.NH.
- CO₂.C₂H₅ (Ref 2) or by heating ethylisocy-
cyanate with Trinitroethanol in the presence
of a little ferric acetylacetonate (Ref 3)

Refs: 1) Beil – not found  2) Nitroglycerin
Aktiebolaget, BritP 815477 (1959) & CA 53,
19885 (1959)  3) M.E. Frankel, USP
2978492 (1961) & CA 56, 11875 (1962)

N-Nitrotroethyleurethane,

C₂H₅.N(NO₂).CO₂.C₂H₂(C(NO₂)₂; mw 297.15,
N 23.57%, OB to CO₂ -18.9%; crystals (CCl₄),
mp 50–51°. Prepd by treating the preceding entry with concd nitric acid at 100°

Refs: 1) Beil, not found 2) M.B. Frankel, USP 2978485 (1961) & CA 55, 16429 (1961)

Éthyluréthane de la furfurine. French name for N-Carboethoxyfururine or Urethane Furfurine, described in Vol 2 of Encycl, p C52-R

Éthyluréthane de la morpholine. French name for N-Carboethoxymorpholine or Urethane Morpholine, described in Vol 2, p C53-L

Ethylvalerate and Derivatives

Ethyl-n-valerate, CH₃CH₂CH₂CH₂COO.C₂H₅; mw 130.18; liq, sp gr 0.877 at 20°, fp -91.2°, bp 145.5°; sl sol in w, misc with alc & eth. It can be prepd by electrolysis of sodium propionate and potassium ethlylsuccinate

Refs: 1) Beil 2, 300–1 (130) & [266] 2) W.V. Miller & H. Hofer, Ber 28, 2434 (1895)

Ethyl-iso-valerate,

CH₃.CH(CH₃).CH₂.COOC₂H₅; mw 130.18; liq, sp gr 0.867 at 20/4°, fp -93.3°, bp 135°; sl sol in w, misc with alc, eth & benzo. It can be prepd by reacting isopropylidene with sodium acetateester and distilling the product from sulfuric acid


2-Azido-ethyl-n-valerate,

CH₃.CH₂.CH₂.N₃.COOC₂H₅; mw 171.19, N 24.54%; liq, bp 65–70°(2.8mm Hg). Prepd from the 2-bromo compd and NaN₃ in aq alc

Refs: 1) Beil, not found 2) R.M. Moriarty & M. Rayman, Tetrahedron 21(10), 2877–91 (1965) & CA 64, 3312 (1966)

5-Azido-ethyl-n-valerate,

N₅CH₃.CH₂.CH₂.COOC₂H₅; mw 171.19, N 24.54%; liq, bp 105–07°(13mm Hg). Prepd from the 5-bromo compd and NaN₃


2-Azido-ethyl-isovalerate,

CH₃.CH(CH₃).CH(N₃).COOC₂H₅; mw 171.19, N 24.54%; liq, sp gr 1.0181 at 25°, bp 68–68.5° (8mm Hg), nD 1.4338 at 25°. Prepd by heating the 2-bromo compd with NaN₃ in aq alc

Refs: 1) Beil 2, 318 (139) 2) M.O. Forster & R. Müller, JChemSoc 95, 198 (1909)

2-Nitro-ethyl-n-valerate,

CH₃.CH₃.CH₂.CH(NO₂).COOC₂H₅; mw 175.18; N 7.94%; yel liq, sp gr 1.0551 at 18/4°, bp 51–52°(0.1mm Hg), nD 1.4595 at 18°(1.4274 at 20°); sol in alc, eth & benzo. Prepd by shaking H₂O₂ in H₂SO₄ with the 2-nitroso compd

Refs: 1) Beil 2, (132) 2) J. Schmidt & H. Dieteler, Ann 377, 49 (1910)

3-Nitro-ethyl-n-valerate,

CH₃.CH₂.CH(NO₂).COOC₂H₅; mw 175.18; N 7.94%; liq, bp 105–10°(15mm Hg, contains 12% of the 3-bromo parent). Prepd by heating at 60° in dimethylformamide NaN₃, 3-bromo-ethyl-n-valerate & phloroglucinol


4-Nitro-ethyl-n-valerate,

CH₃.CH(NO₂).CH₂.CH₂.COOC₂H₅; mw 175.18, N 7.94%; liq, sp gr 1.0955 at 20/4°, bp 94–95° (1mm Hg, Ref 2), 68–71°(1mm Hg, Ref 3), nD 1.4315 at 20°. Prepd from nitroethane and ethylacylate in liq ammonia (Ref 2) or with benzyliiethylammonium hydroxide as cata-lyst (Ref 3)


5-Nitro-ethyl-n-valerate,

O₅.N.CH₃.CH₂.CH₂.CH₂.COOC₂H₅; mw 175.18, N 7.94%; liq, sp gr 1.075 at 25°, bp 250–55° (dec), nD 1.4344 at 25°. Prepd by heating at 85° in w NaN₃ and 5-bromo-ethylidipropionate


2-Nitro-ethyl-isovalerate,

CH₃.CH(CH₃).CH(NO₂).COOC₂H₅; mw 175.18, N 7.94%; liq, sp gr 1.0701 at 20°, bp 60°(1mm
Hg), n D 1.4269 at 20°. Prepd by reacting NaN 3, 2-bromo-ethyl-iso-valerate & phloroglucinol in dimethylosulfoxide or dimethylformamide
Refs: 1) Beil, not found 2) N. Komblum et al, JACS 79, 2507–9 (1957) & CA 51, 13795 (1957)

4-Nitro-ethyl-iso-valerate,
O 2N.CH 2.CH(CH 3).CH 2.CO.O.C 2H 5; mw 175.18, N 7.94%; liq, sp gr 1.100 at 25°, bp 113° (9mm Hg), n D 1.435 at 25°. Prepd by heating at 60° nitromethane and ethylcrotonate

4,4-Dinitro-ethyl-n-valerate,
CH 2.C(NO 2) 2.CH 2.CH 2.CO.O.C 2H 5; mw 220.18, N 12.73%; soln in CCl 4. The only literature reference to this compd is for a procedure to extract it from a mixture with other expds.
May have been prepd by reacting dinitroethylene with ethylacrylate, in analogy with the preceding mononitro compds

4,4-Trinitro-ethyl-iso-valerate,
(O 2N) 3C.CH(CH 3).CH 2.CO.O.C 2H 5; mw 265.18, N 15.84%, OB to CO 2 ~69.4%; liq, bp 91–91.5° (0.65mm Hg), n D 1.4537 at 20°. Prepd by refluxing in alc nitroform and vinylacetic acid

Tetranitro-ethylvalerate, mw 310.18, N 18.07%, OB to CO 2 ~46.5%. There is no reference to this compd in the open literature
Refs: 1) Beil, not found 2) CA, not found

4,4-Dinitro-(2,2,2-trinitroethyl)-n-valerate,
CH 3.C(NO 2) 2.CH 2.CH 2.CO.CH 2.C(NO 2) 2; mw 355.18, N 19.72%, OB to CO 2 ~29.3%; crysrs, mp 93.5–94.5°. Prepd by esterifying 4,4-dinitrovaleric acid with 2,2,2-trinitroethanol in the presence of polyphosphoric acid at 40–80°

Ethylvinyl Corbinol or Pentene-1-ol-3,
CH 2.CH.CH(OH).C 2H 5; mw 86.13; liquid, sp gr 0.840 at 19.5/0°, bp 114.5–114.7°. Prepd from acrolein and dieethylzinc

Ethylvinyl Ether or Vinylethyl Ether,
CH 2.CH.O.C 2H 5; mw 72.10; colorless liq, sp gr 0.754 at 20/20°, fr p ~115.3°, bp 35.5°, n D 1.3739 at 20°, fl p <0°F; v sl soln in w; soln in alc.
Can be prepd by reaction of acetylene with ethanol, followed by washing with w, drying in presence of alkali and distillation from metallic Na.
It is extremely dangerous & reactive and can be polymerized in either the liquid or vapor phase.
It is used as an intermediate and for copolymerization

Ethylvinyl Hexoate or Vinyl-2-ethyl Hexoate,
CH 2.CH.OOC.CH(C 2H 5).C 2H 5; mw 170.25; liq, sp gr 0.8751 at 20/20°, fr p ~90°, bp 185.2°, fl p 165°F; insol in w. It can be prepd from acetylene, 2-ethylhexanoic acid, zinc oxide and Raney nickel heated under pressure.
Used in polymers and emulsifying paints

Ethylvinylhexyl Ether or Vinyl-2-ethylhexyl Ether,
CH 2.CH.O.CH 2.CH(C 2H 5).C 2H 5; mw 156.27; liq, sp gr 0.8102 at 20/20°, fr p ~100°, bp 177.7°, fl p 135°F; insol in w. It can be prepd by reacting vinyl alcohol with 2-ethylhexanol over alkaline diatomaceous earth at 275°.
Used as intermediate in
pharmaceuticals, insecticides and adhesives
Refs: 1) Beil, not found 2) R.I. Hoaglin & D.H. Hirsh, USP 2566415 (1951) 3) Cond-

Ethylnylnpyridine or 2-Vinyl-5-ethylpyridine, (CH₃CH)₂C₆H₄N(C₂H₅)₂, mw 133.19, N 10.52%;
liquid, sp gr 0.9449 at 20/20°, fr p –50.9°, bp 138° at 100mm, fl p (Cleveland open cup) 200°F;
ven pressure 0.2mm at 20°; sol in w, alc, eth & chl. It can be prepd by heating
5-ethyl-2-[hydroxyethyl]-pyridine with concd HCl at 165°. Used as copolymer and in syn-
thesis
Refs: 1) Beil 20, 262 & [173] 2) G. Prausnitz, Ber 25, 2394(1892) 3) Cond-

Ethylxylene and Derivatives
Ethylxylene, Ethylmethylenbenzenes or Dimethylenbenzenes, C₆H₅C₆H₄(CH₃)₂;
mw 134.21. The following isomers are listed in refs:
4-Ethyl-o-xylene, colorless liq, sp gr 0.875
at 20/4°, fr p –67.0°, bp 189.8°; insol in w;
sol in alc or eth. Prepn & other props in Ref 1
2-Ethyl-m-xylene, liq, bp 80–83°(24mm), nD
1.5040 at 24°. Prepn in Ref 5
5-Ethyl-m-xylene, colorless liq, sp gr 0.866
at 20/4°, fr p –84.2°, bp 183.8°; insol in w;
sol in alc or eth. Prepn & other props in Ref 2
4-Ethyl-p-xylene, colorless liq, sp gr 0.876
at 20/4°, fr p –63.0°, bp 188.4°; insol in w;
sol in alc or eth. Prepn & other props in Ref 3
2-Ethyl-p-xylene, colorless liq, sp gr 0.877
at 20/4°, fr p –53.7°, bp 186.9°; insol in w;
sol in alc or eth. Prepn & other props in Ref 4
4) Beil 5, 428, (206) & [382] 5) L.I.
Smith & M.A. Kieas, JACS 61, 995 (1939)

Azidoethylxylene, mw 175.22, N 24.00%.
There are no literature references to a compd
of this type
Refs: 1) Beil, not found 2) CA, not found
5-Nitro-4-ethyl-m-xylene,
C₆H₅C₆H₄(CH₃)₂NO₂; mw 179.21, N 7.82%
Infrared spectrum reported in Ref 2; the
authors stated the prep of this new compd
was unimportant, and failed to list any props
Refs: 1) Beil, not found 2) A. van Veen
et al, Rec 76, 801–9 (1957) & CA 52, 4321
(1958)
6-Nitro-4-ethyl-m-xylene,
C₆H₅C₆H₄(CH₃)₂NO₂; mw 179.21, N 7.82%;
liq, bp 270–27°(sl. dec). Prepd from the parent
in cold concd nitric acid
Refs: 1) Beil 5, 429 2) A. Tölh & A.
Geyger, Ber 25, 1535(1892)

Dinitroethylxylene, mw 224.21, N 12.50%.
There are no references to a compd of this type in the open literature
Refs: 1) Beil, not found 2) CA, not found

3,5,6-Trinitro-4-Ethyl-o-xylene,
C₆H₅C₆(NO₂)₃(CH₃)₂; mw 269.215, N 15.61%;
ndls (alc), mp 121°. Prepd by nitration of the
parent with mixed acid (Ref 3)
Refs: 1) Beil 5, 428 & [382] 2) J. Stahl,
Ber 23, 992 (1890) 3) K. v.Auwers & K.
Ziegler, Ann 425, 258(1921)

4,5,6-Trinitro-2-ethyl-m-xylene,
C₆H₅C₆(NO₂)₃(CH₃)₂; mw 269.215, N 15.61%;cryst,
mp 181°. Prepd by refluxing the parent in
mixed acid
Refs: 1) Beil, not found 2) L.I. Smith &
M.A. Kieas, JACS 61, 989–96 (1939) & CA
33, 5573(1939)

2,5,6-Trinitro-4-ethyl-m-xylene,
C₆H₅C₆(NO₂)₃(CH₃)₂; mw 269.215, N 15.61%;
ndls (alc), mp 127°, sol in alc. Prepd by mixed
acid nitration of the parent
Refs: 1) Beil 5, 429 2) F. Fittig & T.
Ernst, Ann 139, 193(1866)

2,4,6-Trinitro-5-ethyl-m-xylene,
C₆H₅C₆(NO₂)₃(CH₃)₂; mw 269.215, N 15.61%;
ndls (alc), mp 238°. Prepd by mixed acid
nitration of the parent
Refs: 1) Beil 5, 429 2) O. Jacobsen, Ber 7,
1434(1874)
3,5,6-Trinitro-2-ethyl-p-xylene,
C₆H₆.C₄(NO₂)₃(CH₃)₂; mw 269.215, N 15.61%;
prisms (alc), mp 129°. Prepd by nitration of
the parent
Refs: 1) Beil 5, 428 2) O. Jacobsen, Ber 19,
2516(1886)

Ethylxylidines and Derivatives

Ethylxylidines, Ethylvaminoxylene, Dimethyl-
N-ethyl-anilines or N-Ethyl-dimethylanilines,
C₆H₅.NH.C₆H₄.CHCH₃; mw 149.24. Prepns
for the following isomers are given in the
indicated refs:
3-(N-ethyl)-m-xylidine or sym-N-Ethyl-m-
xylidine, liq, bp 120–22°(15–16mm Hg);
Perchlorate, mp 171–75°; Picrate, mp 148–49°
(Ref 2)

3-(N-ethyl)-o-xylidine or N-Ethyl-vic-o-
xylidine, liq, bp 227–28°(Ref 1)

N-Ethyl-p-xylidine, liq, bp 222–23°(748mm Hg)
(Ref 3)
Refs: 1) Beil 12, 1101 2) Tetrahedron,
Suppl 7, 9–25(1966) 3) Beil 12, 1137

Azidoethylxylidine, mw 190.25, N 29.47%.
There are no references to this compd in the
open literature
Refs: 1) Beil, not found 2) CA, not found

5-Nitro-4-(N-ethyl)-o-xylidine,
C₆H₅.NH.C₆H₄.CH(CH₃)₂.NO₂; mw 194.24,
N 14.43%; om crysts (alc), mp 71–74°. Prepd
by making the p-toluenesulphonamide of the
non-ethylated xylidine, reacting with ethyl-
iodide to make the N-ethyl compd, and then
heating in sulfuric acid
Refs: 1) Beil, not found 2) J. J. Ursprung,
USP 3179669(1965) & CA 63, 11373(1965)

4,6-Dinitro-3-(N-ethyl)-o-xylidine,
C₆H₅.NH.C₆H₄.CH(CH₃)₂.NO₂; mw 239.24,
N 17.57%; om ndls (alc), mp 75–76°. Prepd
from 3,4,6-trinitro-o-xylene and ethylamine in
alc
Refs: 1) Beil 12, (479) 2) A.W. Crossley
& W.R. Pratt, JChemSoc 103, 987(1913)

3,5-Dinitro-4-(N-ethyl)-o-xylidine,
C₆H₅.NH.C₆H₄.CH(CH₃)₂.NO₂; mw 239.24,
N 17.57%; om ndls (alc), mp 115°; sol in
benz & chl. Prepd from 3,4,5-trinitro-o-
xylene and ethylamine in alc
Refs: 1) Beil 12, (481) 2) A.W. Crossley
& W.R. Pratt, JChemSoc 103, 986(1913)

3,5-Dinitro-2-(N-ethyl)-p-xylidine,
C₆H₅.NH.C₆H₄(CH₃)₂(NO₂)₂; mw 239.24,
N 17.57%; cryspts, mp 133°. Prepd by heating
trinitro-p-xylene with ethylamine
Refs: 1) Beil 12, 1141 & [618] 2) J.J.
Blankesma, Rec 24, 51(1904)

2,4,6-Trinitro-5-(N-ethyl)-m-xylidine,
C₆H₅.NH.C₆H₄(CH₃)₂(NO₂)₃; mw 284.24,
N 19.72%; cryspts, mp 122°. Prepd from 2,4,6-
trinitro-5-methoxy-m-xylene and ethylamine
in alc
Refs: 1) Beil 12, 1133 2) J.J. Blankesma,
Rec 21, 331(1902)

N,3,5-Trinitro-2-(N-ethyl)-p-xylidine,
C₆H₅.N(NO₂)₂.C₆H₄(CH₃)₂(NO₂)₂; mw 284.24,
N 19.72%; cryspts (alc), mp 36°. Prepd from
3,5-dinitro-2-(N-ethyl)-p-xylene and nitric acid
Refs: 1) Beil 12, 1141 2) J.J. Blankesma,
Rec 24, 51(1904)

N,2,4,6-Tetranitro-5-(N-ethyl)-m-xylidine,
C₆H₅.N(NO₂)₂.C₆H₄(CH₃)₂(NO₂)₃; mw 329.24,
N 21.27%; cryspts, mp 85°. Prepd from the
2,4,6-trinitro compd above by nitration with
sp gr 1.52 nitric acid
Refs: 1) Beil 12, 1134 2) J.J. Blankesma,
Rec 21, 331(1902)

Ethylxylaside and Derivatives

There is no reference to this compd in the open
literature
Refs: 1) Beil, not found 2) CA, not found

Ethylxylaside Trinitrate,
C₆H₅.C₆H₄N₃O₈.CH₀; mw 313.18, N 13.42%,
OB to CO₂ 43.5%; cryspts, sp gr 1.53 at 20°,
mp 95.5°. Prepd by nitration in HAC/Ac₂O
at 0° ethylxylopyranoside; attempted purifi-
cation of this cyclic ether caused it to open
up to give the xyloside. Loses 3% of weight
in 20 hours at 100°
Refs: 1) Beil, not found 2) G. Fleury et
al, MP 31, 107–20(1949) & CA 46, 11686(1952)
Ethyne. Same as Acetylene described in Vol 1 of Encycl, pp A58-R to A64-R

Ethynylolation. Condensation of acetylene with a reagent such as aldehyde to yield an acetylenic derivative. The best example is the union of formaldehyde and acetylene to produce butyne-diol, HO.CH₂-C≡C.CH₂.OH

Étincelle d'allumage. Fr for Igniting Spark

Étirage des poudres. Fr operation corresponding to Amer "extrusion of propellants". See under Filage des poudres

Éthyl or Heclo Explosive of Atlas Powder Co.
Dynamite contg NG 40, Na nitrate 45, woodmeal 14 & Mg carbonate 1%
Ref: Pérez Ata (1945), 332

Éthyl Powder. An Amer Dynamite which contained NG 15 to 65 with a dope consisting of Na nitrate mixed with woodpulp and/or roused flour
Ref: 1) Daniel (1902), 286  2) Fedoroff & Clift 4(1946), 32

Ét-NENA. Designation of 1-(Ethyl)-nitramino-2-ethanol Nitrate, also known as N-(β-Nitroxy-ethyl)-ethyleneimine. See under Ethylamino-ethanol (Ethylethanolamine and Derivatives) in this Vol, p E203-R

Émite. Mixture of Asphaltine (described in Vol 1 of Encycl, p A406-L) 92 and antimony sulfide 8%
Ref: 1) Daniel (1902), 286  2) Fedoroff & Clift 4(1946), 32

Étouillle. Fr for Primer

Étouillle à percussion. Fr for Percussion Primer

Euler, Leonhard (1707–1783). Swiss mathematician who lived in St Petersburg over 30 years during the reign of Catherine the Great. He was a member of the Russian Academy of Science and one of the first to study, theoretically, the processes taking place in the gun barrel during firing

Eulite (Eulyt, in Ger) or 5-Methyl-4-nitro-3-(1,1-dinitroethyl)-isoxazole, Beil name 4-Nitro-5-methyl-3-[α,α-dinitroethyl]-isoxazol. Called by Quillico et al: γ-Methyl-a-isoxazole-1-dinitro-2-dinitroethane,

H₃C.C–O–N

O₂N.N.C        C₂(NO₂)₂.CH₃
H₃C.C–O–N

H₃₃C           CH

N–O–C–C(NO₂)₂.CH₂.NO₂;

mw 246.14, N 22.76%; OB to CO₂ ~52.0%; prisms (from chl), mp 102.8°; decomps explosively when heated above mp. It was first prep'd by Baup (Ref 2) in impure state, together with Dyslyt (Diselite), C₆H₄N₄O₆, during study of the action of nitric acid on citraconic acid, as was described in Vol 3 of Encycl, p C324-L. Bassett (Ref 3) prep'd eulite by heating aqueous soln of citraconic acid with nitric acid (d 1.42), but he did not establish its structure. Angeli (Ref 4), prep'd eulite of mp 102°. Quillico (Ref 5) prep'd eulite much later by nitrating citraconic anhydride (in lieu of citraconic acid) and he suggested two structural formulas. Quillico & Fusco (Ref 6) prep'd a very explosive Mercuric Salt of eulite by the action of mercuric chloride. It was a red-violet gelatinous compd of the formula C₆H₃N₄O₄.HgCl₂.HgO

Quillico et al. resumed the study of eulite in 1946 and established more definitely its
structure (Refs 7 & 8). In the same year Quilico & Fusco (Ref 9) studied the mechanism of formation of eulite

The structure of Dislite, C₆H₄N₄O₆, obtained by several investigators as a minor companion of eulite on nitration of citraconic acid was not established until 1946 (Ref 10). As Dislite was mentioned but not described in this Encycl, Vol 5, p DI506-L, we are describing it after the refs.


**Dislite (Dyslitx in Ger)**

\[ \text{O}_2\text{N.C} \quad \text{C–C} \quad \text{C.NO}_2 \]

\[ \text{H}_3\text{C.C–O–N} \quad \text{N–O–C.CH}_3 \]

mw 254.16, N 22.05%; long fine ndls (from alc), mp 200.5°; sol in alc; insol in w. It is formed simultaneously with Eulite by reaction of citraconic acid & nitric acid. It forms numerous salts (Refs 1, 2 & 3).

**Refs:** 1) Beil 2, 770 & [1939]; 27, [869] Compd called Bis[4-nitro-5-methylisoxazolyl-3-]


**Eutectic Explosive Mixtures**

Eutectic is a mixture of two or more substances which has the lowest constant melting point of any mixture of its constituents. Usually the molecular ratios of the components can be expressed in simple whole numbers, such as 1:1, 1:2, 2:3, etc.

Following Table lists various eutectic mixtures of explosives. See also BINARY, TERNARY AND QUATERNARY MIXTURES in Vol 2 of Encycl, pp B116 to B120

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*Note 1:* Accdg to Ref 2, p 1026, the binary eutectic temp 26.4° for DNT-TNT was lowered to 25.7° by addns of small quantities of TNX; similarly temp 33.8° of MNIT-TNT was lowered to 30.55° and temp 45.1° of DNT-TNT was lowered to 42.3°.

*Note 2:* Accdg to Ref 14, AN forms the following ternary eutectics: 1) AN 66.5, Na nitrate 21.0 & K nitrate 12.5% (fr p 118.5°); and 2) AN 69, Ca nitrate 18 & Na nitrate 1.3% (fr p 107.5°)

*Note 3:* Eutectic temperature of ternary mixture of three TNT isomers (α 43.5, β 20.0 and γ 36.5%) was given as 44.4° by W.H. Gibson et al in JCS 121, p 282(1922).


16) E. Burtol & P. Tavemier, MP 31, 39(1949)

17) G. Desses, MP 31, 48–49(1949) (Ethyltetrol forms with 30–38% of Tetrol as a eutectic of mp 75–80°)
### Table

**Binary Eutectic Mixtures**

<table>
<thead>
<tr>
<th>Components and Their Melting Points</th>
<th>Approximate % by Weight Ratios</th>
<th>Eutectic Temp °C</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-MNT (50.25°) – DNT (69.54°)</td>
<td>45:55</td>
<td>26.4°</td>
<td>3, p1127</td>
</tr>
<tr>
<td>Molecular Ratio (1:1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-MNT (50.25°) – TNT (80.35°)</td>
<td>55:45</td>
<td>33.8°</td>
<td>3, p1127</td>
</tr>
<tr>
<td>Molecular Ratio 2:1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNT (69.54°) – TNT (80.35°)</td>
<td>55:45</td>
<td>45.1°</td>
<td>3, p1127</td>
</tr>
<tr>
<td>Molecular Ratio 1:1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNT (71°) – TNT (80.6°)</td>
<td>54:46</td>
<td>45°</td>
<td>8a, p233</td>
</tr>
<tr>
<td>TNT (80.6°) – 2,4,5-TNT (101.5°)</td>
<td>61:39</td>
<td>58°</td>
<td>8a, p233</td>
</tr>
<tr>
<td>TNT (80.6°) – Tetryl (127.5°)</td>
<td>52:48</td>
<td>65-68°</td>
<td>8a, p233</td>
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<tr>
<td>TNT (80.6°) – Tetryl (127.5°)</td>
<td>67:33</td>
<td>65-68°</td>
<td>8a, p233</td>
</tr>
<tr>
<td>TNT (78.8°) – Tetryl (126.8°)</td>
<td>63:4:36.6</td>
<td>58.8°</td>
<td>5, p3803</td>
</tr>
<tr>
<td>TNT (80.27°) – Tetryl (128.72°)</td>
<td>61.3:38.7</td>
<td>67.4°</td>
<td>4, p73</td>
</tr>
<tr>
<td>Molecular Ratio 2:1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DNT (68.8°) – PA (119°)</td>
<td>60:40</td>
<td>51.6°</td>
<td>8a, p233</td>
</tr>
<tr>
<td>TNT (80.27°) – PA (121.8°)</td>
<td>69:8:30.2</td>
<td>59.4°</td>
<td>4, p795</td>
</tr>
<tr>
<td>TNT (80.6°) – PA (121.7°)</td>
<td>67:33</td>
<td>55.5°</td>
<td></td>
</tr>
<tr>
<td>Tetryl (128.72°) – PA (121.8°)</td>
<td>55.6:44.4</td>
<td>70°(about)</td>
<td>4, p1070</td>
</tr>
<tr>
<td>Molecular ratio 1:1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>p-MNT (51.2°) – TNX (182.0°)</td>
<td>98:2</td>
<td>50.5°</td>
<td>2, p1026</td>
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<tr>
<td>DNT (69.4°) – TNX (182.0°)</td>
<td>94:6</td>
<td>67.7°</td>
<td>2, p1026</td>
</tr>
<tr>
<td>TNT (80.5°) – TNX (182.0°)</td>
<td>92.8</td>
<td>74.8°</td>
<td>2, p1026</td>
</tr>
<tr>
<td>m-DNB (69.5°) – Tetryl (126.8°)</td>
<td>66.5:33.5</td>
<td>65.5°</td>
<td>5, p3803</td>
</tr>
<tr>
<td>DNT (69.4°) – Tetryl (126.8°)</td>
<td>79.5:20.5</td>
<td>59.1°</td>
<td>5, p3803</td>
</tr>
<tr>
<td>DNP (111.4°) – Tetryl (126.8°)</td>
<td>43.3:57.7</td>
<td>83.1°</td>
<td>5, p3803</td>
</tr>
<tr>
<td>PA (122.4°) – Tetryl (126.8°)</td>
<td>43.57</td>
<td>75-77°</td>
<td>5, p3803</td>
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<td>78.3°</td>
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Abbreviations: AN – Ammonium Nitrate; DNAn – Dinitramoline; DNAns – Dinitrmanisole; DNB – Dinitrobenzene; DNCB – Dinitrochlorobenzen; DNCr – Dinitrocresole; DNPh – Dinitrophenol; DNT – 2,4,6-Dinitrotoluene; En – Erythritol Tetranitrate; HNDPhA – Hexanitrodiphenylamine; MHeN – Mannitol Hexanitrate; MNPh – Mononitrophenol; MNT – Mononitrotoluene; PA – Picric Acid; PETN – Pentaerythritol Tetranitrate; TNAn – Trinitramoline; TNAns – Trinitramisole; TNB – Trinitrobenzene; TNCr – Trinitrocresole; TNPh – Trinitrophenol; TNT – 2,4,6-Trinitrotoluene; TNX – Trinitro-m-xylene
Ternary Eutectic Mixtures

<table>
<thead>
<tr>
<th></th>
<th>% by Weight</th>
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<tr>
<td>MNT</td>
<td>48.5</td>
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<tr>
<td>DNT</td>
<td>43.5</td>
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<tr>
<td>TNT</td>
<td>52.5</td>
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<tr>
<td>Eutectic</td>
<td>44</td>
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<tr>
<td>Temp, °C</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
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<tr>
<td></td>
<td>10.0</td>
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<tr>
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<td>52.5</td>
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<td>44</td>
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<td>52.5</td>
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<td></td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>52.5</td>
</tr>
</tbody>
</table>

Reference 3, p1130

Eutectic Alloys. See under Fusible Alloys

Euxenite (Loranskite). (Y, Ca, Ce, U, Th)-
(Nb, Ta, Ti)\textsubscript{2}O\textsubscript{6}. A rare-earth mineral, occurring in Norway, Madagascar, Canada & Pennsylvania. It is brownish-black, brilliant to vitreous; sp gr 5.0-5.9 and hardness 5-6. Used as a source of uranium, niobium and tantalum

Ref: CondChemDict (1961), 480-R; 8th edit (1971), not found

Evaluating Explosives and Hazardous Materials, Methods of US Bureau of Mines for are described by C.M. Mason & E.G. Aiken as IC (Information Circular) 8541 (1972); can be ordered from Sup of Document, US Govt Printing Office, Washington, DC 20402

Evaporation. See under DISTILLATION in Vol 5 of Encycl, pp D1509 to D1511 and also under Drying, pp D1560-R to D1565-L

"Everdur". Trademark of Anaconda American Brass Co, Waterbury, Conn 06720 for a group of Cu-Si alloys, with compas adjusted to hot and cold working, hot forging, welding, free machining, and for ingots for remelting and casting. The most widely used alloy in this group is "Everdur 1010", with nominal comp of Cu 95.80, Si 3.10 & Mn 1.10%. In most environments "Everdur" alloys are equivalent to Cu in corrosion resistance


Everling & Kandler patented in 1894 (Ref 1) a smokeless propellant containing nitrated wood cellulose previously treated to render it amorphous. For this pretreatment woodpulp was left for 10-12 hours in 10% Na hyposulfite solution maintained at 30° and then washed with water and dried. Nitration was done in the same manner as for cotton (Ref 2)

Refs: 1) FrP 238258 (1894) 2) Daniel (1902), 287

Evangelidis Explosive (1904). K chlorate 62.5, K ferrocyanide 30.0, charcoal 4.5 & glycerine 3.0%

Ref: Giua, Trattato 6(1)(1959), 398

"Evonohm". Trademark of Wilbur B. Driver Company, Newark, NJ for an alloy of 75% Ni, 20% Cr, 2.5% Al & 2.5% Cu. It has been used in the form of wire in precision wound resistors

Ref: CondChemDict (1961), 480-R; (1971), p 376-R

Eversoft Plastex (British). NG+NGc 25.5, CollodCotton 0.5, Di- & Tri-nitrolicenes 2.5, AN 35, woodmeal 2.5 & Na chloride 34%. Ballistic Pendulum Swing 2.45 inches, vs 3.27 for 50% Gelignite (Standard)

Ref: Marshall 3(1932), 120

Eversoft Seamex (Briz). NG+NGc 10, AN 66, woodmeal 9 & NaCl 15%. Ballistic Pendulum Swing 2.67 inches

Ref: Marshall 3(1932), 120
Eversoft Tees Powder (Brit). NG 10, AN 60, woodmeal 10 & NaCl 20%. Ballistic Pendulum Swing 2.55 inches (See also Tees Powder) Refs: 1) Marshall 3(1932), 120 2) Thorpe 4(1940), 556

EW. Abbr for Electronic Warfare

EW (Exploding Wire). See EXPLODING BRIDGE WIRE (EBW) in this Vol

EWP Thickened Fuels were described by T.L. Wheeler in OSRD 5524 (PBL 28624) (1945) and in OSRD 5524a (PBL 28625) (1945) under the title "Thickened EWP Fuels and Ejection Devices for EWP Fuels"

The EWP (Eutectic White Phosphorus) fuel consists of white phosphorus 55 & phosphorus sesquisulfide 45% by weight. The compn by elements is 80% P & 20% S. The compn of the fuel is not critical and a reasonable deviation is allowable. The fuel is a clear, yel, heavy liq of low surface tension, moderate viscosity, and oily appearance. The specific gravity of the eutectic is 1.840 at 20° and it freezes at approx -42°C. Upon exposure to light for several days, it gradually deteriorates and becomes turbid. When stored in the dark, or in opaque containers, no deterioration takes place.

When the above EWP is ejected from a nozzle it ignites and the flaming liq tends to spray out into the air in a bushy pattern somewhat resembling that obtd when using unthickened hydrocarbon fuels in a conventional portable flame thrower. It was considered desirable to modify the EWP fuel so as to obtain it in thickened, preferably gel, form for improved ballistic characteristics & increased range. The most successful mix found was an emulsion of equal parts by wt of rubber cement & EWP, preferably with the addn of Na bicarbonate. Very good combustion and a range of 60 yds were obtd with a mixt of 8 gallons of asphalt flux & 1 gal of EWP. EWP fuels are ejected by blame-throwers or other ejection devices


Exactor. A "cartridge-actuated device" (See Vol 2 of Encycl, p C71) intended to release the safety mechanism of another cartridge-actuated device. The exactor operates by gas pressure supplied from the "initiator"
Ref: Glossary of Ord (1959), 109-R

Exaltation. The amt by which the molecular refractivity of a compd exceeds the sum of the refractivities of its atoms; it is an indication of constitution (presence of double bonds, etc)
Ref: Hackh's (1944), 328-L

Excavation, Instant (of Corps of Engineers). See Explosive Excavation, Instant

Excavation by Means of Explosives is described in Blasters'Hdb (1966), pp 385-92 (under Grade Construction) and pp 473-74 (Excavating in Hard Ground)
Excelsior Mill. It consists of two vertical discs, one of which is securely fastened to the casing of the machine, while the other is keyed to a revolving shaft. The surfaces of the discs which face each other are fitted with cylindrical teeth arranged in circles of constantly-decreasing diam as they approach the center of the plates. Teeth of the rotating disc pass between those of the fixed disc. The movable disc revolves at high speed, the material being fed at the center of the disc and delivered from the periphery in a very fine state of division.

The Excelsior Mill was used for grinding of oxidizing materials & other constituents used in expl comps
Refs: 1 Colver (1918), 462 2 Perry (1963), not found

Excentric Pressed Propellant Grains. Supposedly concentric propelnt grains are usually slightly excentric. So long as an excentric grain does not have its exterior & interior burning surfaces cutting each other, it behaves like a concentric grain and the unburned or burned portions act as expected. If the propelnt grain is not excentric, the proportionality is maintained. After contact is established between interior & exterior burning surfaces, the burned portion increases more slowly with time than with concentric grains. Correspondingly, the unburned portion diminishes more slowly. Thus, by excentric pressing, the burning time of a propelnt may be increased
Refs: E. Kleider, SS 38, 131–33 (1943) & CA 38, 2823 (1944)

Exchange Coefficient. See Coefficient d’échange (Fr) in Vol 3 of Encycl, p C389-L

Exchange Reaction. A process whereby atoms of the same element in two different molecules or in two different positions in the same molecule transfer places. Exchange reactions are usually studied with the aid of a tracer or tagged atom
Refs: CondChemDict (1961), 481-L

Excitation or Activation. The disturbance of an electron so that it passes from its normal orbit to one of higher energy content as the result of the absorption of radiation. It differs from ionization in the degree to which the electron is separated, as expressed by the equations:

\[ \text{Excitation} \]
\[ a) \ H_2 + h\nu = H_2^* \]
\[ b) \ H_2 + \text{e}^* = 2\text{H}^* \]

\[ \text{Ionization} \]
\[ c) \ H_2 = H_2^+ + \text{e}^- \]
\[ d) \ H_2 = \text{H}^+ + \text{H}^- \]
\[ e) \ H_2^+ = \text{H} + \text{H}^+ + \text{e}^- \]

where \( h\nu \) is a quantum, \( \text{e} \) an electron, \( H_2^* \) an excited and \( H_2^+ \) an ionized molecule, \( \text{H}^+ \) an excited and \( \text{H}^- \), \( \text{H}^+ \) ionized atoms. On returning from the excited to the normal state, the absorbed radiation is emitted, ie, the substance is luminescent or fluorescent
Refs: Hackh’s (1944), 328-L

Excitation. Accdg to Glossary of Ord (1959), p 109-R, it can be applications of 1) signal to the input of a vacuum tube amplifier; 2) signal power to a radio transmitting antenna; or 3) current to the transmitting or receiving elements of a synchro or self-synchronous device

Excrement (Carbonized) Explosives. The following mixtures were patented in Canada during WWI: AN 50–80, carbonized excrement 10–20, metals or metal compds 5–20 & organic nitrocomps 2–20%
Refs: J. Grond, CanadP 165018 (1915) & CA 9, 3363 (1915)

EXE Powder. Brit brown powder used for a while after 1876 in cannons of 152mm as a replacement for BKHR, known as P (Pebble) Powder, which was in the form of cubes. EXE Powder was in the form of prisms with one central canal and with one of its bases being hollow and with grooves
Refs: Daniel (1902), 287 & 595
**Execution of Safety.** The chem & physical prop of an expl determine its capabilities. As these props are "built in" it is important that expls be selected from manufacturers who exercise great care in making their products and who have the necessary research, physical & chem control, manufg skill, and test facilities to make certain that their expls measure up to the high degree of uniformity & high quality reqd by modern industry. In considering the props of expls that affect execution of safety, the following are important: strength, sensitiveness, stability, rate of deton, water resistance & consistency. 
*Ref:* J.J. Berliner & Staff, "Explosives", Pamphlet, NY (1953)

**Exercise Head, Guided Missile.** An item designated to simulate a warhead of guided missile. It may or may not contain telemetrying devices and/or flash signals. 
*Ref:* Glossary of Ord (1959), 109-R

**Exercise Head, Torpedo.** An item designed for attachment to a torpedo main assemblage to complete a torpedo for a practice run. It may contain recording instruments. 
*Ref:* Glossary of Ord (1959), 109-R

**Exerciser, Recoil Mechanism.** An item specifically designed for exercising hydropneumatic recoil mechanism. It usually consists of a power unit, a hydraulic system and a control system. It may be trailer mounted. Recoil mechanism can also be artificially exercised by mechanical means, without removing it from storage. The machine for such exercising is known as gymnasticator. 
*Ref:* Glossary of Ord (1959), pp 109-R & 144-L

**Exo.** A prefix indicating that an element or radical is substituted for hydrogen atom attached to a side chain atom, while "eso" means substitution in the ring. 
*Refs:* 1) A. Baeyer, Ber 17, 962(1994) 
2) Hackh's (1944), p 382-R

**Exograph.** A radograph taken by means of X-rays (röntgenograph). A radograph taken with γ rays is known as gamma graph. 
*Ref:* Hackh's (1944), pp 328-R & 719-R

**Exos** (Upper-Amosphere Research Rocket). A high-altitude sounding rocket developed for the Air Force Cambridge Research Center by University of Michigan ResInst with the assistance of NASA. Diam of rocket 22.88 inches, length 42.46 ft, payload 40 lbs and altitude 300 miles. It is a three-stage rocket consisting of an Honest John (booster), a Nike-Ajax (booster) 2nd stage and a Recruit rocket as 3rd stage. Payload consisted of a nose cone, skin temp sensing equipment and a radar beacon & telemetry devices. 

**Exothermic Reaction.** A reaction in which heat is liberated. It usually proceeds rapidly; sometimes explosively. In an endothermic reaction a chemical change proceeds slowly with absorption of a definite number of calories. 
*Ref:* Hackh's (1944), 328-R (Exothermic); 305-R (Endothermic)

**Exothermic Reaction Mixtures for Underwater Propulsion and Ignition Devices.** Accdg to Lemke (Ref) of Aerojet-General Corp, pressure stability and burning rate of solid rocket fuels are improved during combstn by incorporating finely divided iron in a quantity of about 1%. The proplts investigated were mixtures of finely divided metals: Al, Be & Mg with perchlorates of K, Li & Na. 
*Ref:* A.E. Lemke, GerP 1158884(CIC 06d), Dec 5, 1963 & CA 60, 9094(1964)
Exotic Fuels. Accdg to Ref 1, this name is applied to high energy fuels (HEF) for jets and rockets which have higher performance rates than hydrocarbon fuels, such as kerosene or JP-6, etc. The term has also been used to refer specifically to those jet and rocket fuels based on boron hydrides. Such fuels, known as Boranes, are described in Ref 2.

Exotic fuels are also known as ultimate fuels for jets and rockets [G.A.W. Boehm, Fortune (Dec 1957), pp 165–68, 170, 172, 177 & 178] (See also Jet Fuels and Rocket Fuels)


Exotic Propellants. Like exotic fuels, exotic propellants are novel propellants that offer the promise of greater energy. Propellants that have different common linkages, such as B-H and C-F, can theoretically liberate greater energy by oxidation than can the common hydrocarbon propellants because greater net energy is available after oxidation of such linkages. Note that fluorine is the oxidizer and boron is the reducing agent in such arrangements. It is also important to remember that boron, used as a fuel alone liberates 29000 BTU/lb when oxidized compared with 19000 BTU/lb liberated by hydrocarbons; a 40% increase


Expanding Bullets. See Expansive Bullets


Expansion. An increase of dimension. It can be: cubical or volume expansion – increase in three dimensions; linear – increase in length; thermal – increase in volume due to increase in temperature. The rate varies with temp and depends on the coefficient of thermal expansion, which is defined in Ref 2 and described more fully below under “Expansion, Thermal Coefficient of”

Refs: 1) Hackh’s (1944), 328-R 2) PATR 2700, Vol 3(1966), C391-L

Expansion Equations are given in Hackh’s (1944), p 328-R

Expansion, Lateral, also known as Dispersion in Detonation is described in Vol 4 of Encycl, pp D421-R to D423-L, under “Detonation (and Explosion), Lateral Expansion (Dispersion) and Lateral Loss in”

Expansion Ratio. In jet propulsion it is the ratio of the nozzle exit section area to the nozzle throat area. In cartridge actuated device, it is the ratio of final to initial volume in a stroking type of CAD

Ref: Glossary of Ord (1959), 109-R

Expansion, Thermal Coefficient of. Coefficient of Thermal Expansion (Wärmeausdehnungskoeffizient, in Ger) is defined in Vol 3 of Encycl, p C391-L.

The general equation which is applicable to linear, superficial or cubical coefficients of expansion, may be expressed as:

$$m_1 = m_0 \left(1 + \alpha t + \beta t^2 + \gamma t^3 + \ldots \right),$$

where: $m_1$ = length, area or volume at $t$°C

$m_0$ = same at temp 0° C

$\alpha$, $\beta$, & $\gamma$ = empirically detd coefficients

For solids, if a linear coeff $(L)$ is known, the superficial coeff is approx $(2L)$ and the cubical $(3L)$

Coefficients of thermal expansion of exps and related compds are given in this Encycl, wherever available, under each compd
Explosion Wave. In aerodynamics expansion wave is a pressure wave that has the effect of decreasing the density of air as the air passes thru it, while the compression wave has the effect of increasing density of air. Ref: Glossary of Ord (1959), p 109-R (Expansion Wave); p 78-L (Compression Wave)

Explosive or Expanding Bullets. Before about 1860, all small arms were smooth bore and bullets were ball-shaped & made of lead. Since the balls were loaded thru the muzzle (on top of previously introduced BkPdr charge serving as a propellant), it was not convenient to make them fit too tightly in the barrel. As result of this, part of propelling gases escaped during firing thru small openings between the bullets and the barrel towards the muzzle, without contributing to propelling force. This was undesirable because it decreased the muzzle velocity and shortened the range.

In order to prevent the loss of propelling gas and thus improve the performance of small arms, W. Greener and Captain Minie introduced in the 2nd quarter of the 19th century the so-called explosive or expanding bullets. They were lead bullets which were enlarged in diameter by driving into them, during firing, of special plugs which were placed on top of the BkPdr charge and under the bullet.

Small arms using Minie's bullets were adopted by the French Army about 1849 and used as late as the Crimean War (1853–1856), although at that time some drilled weapons started to be used.


Expedit. One of the Brit permitted expls contg no NG: TNT 12, AN 34.5, K nitrate 33, Amm chloride 20 and moisture 0.75 parts. Maximum chge 32 oz and swing 2.62 inches (vs 3.27 for Gelignite contg 60% NG).


Expelling or Ejecting Charge. See Vol 2 of Encycl, p C150-L, under CHARGE

Expansible. It refers to a supply item that is consumed, or loses its identity when used; expected to be consumed or to lose its identity.

Ref: 1) Glossary of Ord (1959), 109-R
2) OrdTechTenn (June 1962), 144-R

Experimental Procedures in Detonation (and Explosion). See under DETONATION (AND EXPLOSION), EXPERIMENTAL PROCEDURES in Vol 4 of Encycl, p D299-R to D346-L

Experimental Procedures for Determination of Properties of Detonation Waves are discussed in Refs: 3, 32, 35, 44, 57, 67, 68, 69, 75, 94, 95a & 96 listed in Vol 4 of Encycl, pp D724-R to D730-L
Experimental Type. In order to understand the meaning of it, we are describing here type classification as given in Ref, pp 306-L and 307-L & R. Under this type are understood designations made by technical committee action to record the status of items of materiel from the standpoint of development and suitability for service use. Those designations and their definitions are as follows:

A) Development Type. Designates an item being developed to meet a military requirement. This category is further classified in the Ordnance Corps as follows:

1) Experimental Type. Materiel that is being developed or modified to meet approved military characteristics or to improve design or function

2) Service Test Type. Materiel which has performed satisfactorily in engineering tests and is authorized to be procured in limited quantity for user test (See Note 1 below)

B) Adopted Type. Designates an item which has been found suitable for its intended military purpose and which has been type classified. This category is further classified as follows:

1) Standard Type. Designates the most advanced and satisfactory item or assemblage that has been adopted and is preferred for procurement

2) Substitute Standard Type. Designates an item or assemblage which is not so satisfactory as the standard type, but is a usable substitute therefor. It may be procured to supplement the supply of the standard type

3) Limited Standard Type. Designates an item or assemblage that is less satisfactory than the standard and substitute std types, but which is acceptable and may be used until the supply is exhausted

C) Obsolete Type. Designates an item or assemblage which has been declared unsuitable for military use

Note 1: On p 310 of the same Ref is described the so-called: User Test, which is an evaluation test, conducted on materiel under development following satisfactory engineering test (See Note 2, below). The test is performed by the using agency to determine the suitability of the developmental materiel for military use. User tests are of two types:

a) Service Test. A test under simulated operational conditions to determine to which degree the item meets the military requirement as expressed in military characteristics

b) Troop Test. A test where a troop unit, equipped with appropriate numbers of the item, operates under actual or simulated field conditions to test the suitability of the item and also the adequacy of the organization, doctrine, technique, training and logistic support required for its use

Note 2: On p 107-L of the same Ref is described the so-called:

Engineering Test. It is an evaluation test of materiel under development conducted by, or under the supervision of, the technical service concerned to determine inherent structural, electrical, or other physical or chemical qualities of the item or system tested, including those of an environmental nature, designed to provide a basis for decisions as to subsequent developmental action or the suitability of the item for user test


Expl(s). Abbr for Explosive(s)

expl. Abbr for explosive (adjective)

expl(s). Abbr for explode(s)

expld. Abbr for exploded

ExpIn. Abbr for Explosion
**explode(s).** To be changed in chemical or physical state usually from a solid or liquid to a gas (as by sudden vaporization or rapid chemical decomposition) so as suddenly to transfer considerable energy into the kinetic form (See also Explosion).

*Ref:* Glossary of Ord (1959), 109-R

**Exploded View.** A drawing of any article or piece of equipment in which the component parts are separated but so arranged as to show their relationship to the whole.

*Ref:* Glossary of Ord (1959), 110-L

**Exploder** is the same as Blasting Machine described in Vol 2 of Encycl, p 212-L. See also Blasters'Hdb (1966), pp 113–119

*Note:* Accdg to NOLTR 1111 (1952), p G2, exploder is an alternate term for a fuze, usually used in connection with torpedoes.

*Exploder.** British name for an expl component containing CE (Tetryl) for use in bombs.


**Exploder, Magnetic.** A magnetic exploder used by the Germans during WWI in sea mines. It coord a compass and, when a magnetic mass (such as a ship) approached, the needle of compass started to swing and this activated the initiating device of the mine.

The American magnetic exploder of Mackie was used in torpedoes. It utilized the variations in the intensity and direction of the earth's magnetic field adjacent to the hulk of a vessel to activate it in the following manner:

When the torpedo was ejected, it rushed thru the water and this spun a small turbine. This, in turn, operated a gear train that pushed the detonator into the booster cavity. The 450 yards of travel of the torpedo required for this operation gave the vacuum tubes within the mechanism time to warm up and to ready the influence feature of the device. When the torpedo entered the magnetic field created by the enemy hull, the EMF generated in the induction coils began to charge. This charge amplified by the vacuum tubes was harnessed to release the firing pin.

When impact rather than magnetism was to induce explosion, the impact dislodged an inertia element which released the firing pin.

The exploder mechanism weighed 91 lbs.


**EXPLODING BRIDGE WIRE (EBW) or EW (Exploding Wire), also known as EEW (Electrically Exploding Wire) (Explodierend Brückendracht in Ger).** EBW phenomenon may be defined as the rapid disintegration (and evaporation) of fine wires under formation of a shock wave, thru abrupt application of high electric energy produced, for example, by a capacitor (condenser) discharge.

*Historical.* Disintegration of fine wires by electrical current released by a Leyden jar (which is actually a condenser) was first observed in 1774 by Brit scientist Nairne (Ref 1), but there was no suggestion for a practical application of this phenomenon (See also Ref 7). It was forgotten until 1920, when Anderson (Ref 2) repeated the experiment of Nairne and reported that the temperatures produced on disintegration of wires approached those of the sun. He did not suggest, however, any practical application of this phenomenon, but raised an interest in it resulting in further experiments which were conducted in Europe, USA and Japan. It seems that the first application of exploding wires to initiate an explosive was done in 1938 by A.F. Belyaev of Russia, as was already mentioned in Vol 4 of Encycl, p D807-L.

In Section 3, Part E, pp D807 to D810-L of Vol 4 are described EBW detonators. There are listed Ref 45 (on p D1032-R) & Ref 46a (p D1033-R) and Additional Refs: Ad97a (p D1044-L), Ad97b (p D1044-L), Ad112a (p
D1045-R), Ad141 (p D1047-R) and Ad160 (p D1052, which contains 20 refs)

The following Refs on EBW were not included in the description of EBW detonators given in Vol 4 of Encycl:

11) M.T. Hedges, "Technical Symposium on Propellant Actuated Devices", Frankford Arsenal, 14–16 June 1961 (Discussion on EW Initiators developed at PicArsn and on their requirements and advantages) 12) M.T. Hedges & E.L. Miller, "Development of an Exploding Bridgewire Ignition Element", PicArsn Ammunition Group Rept 102 (1961) (This item having the configuration of the Mk2Mod2 was developed, along with a suitable EBW firing system. Such an item was not readily susceptible to radiated RF energy) 13) F.D. Bennett, "Shock Producing Mechanisms for Exploding Wires", BRL Rept No 1161 (1962) 14) Anon, "Exploding Wires Energize Laser", C&EN, March 26, 1962, pp 43–4 [The energy obtb from an EW has been used to energize, or "pump" a LASER (See Vol 4 of Encycl, p D436-L, under "Detonation, MASER and LASER in") at Westinghouse Research Laboratories, Pittsburgh, Pa. Scientists at the American Optical Co, Southbridge, Mass have designed a system that may allow using the sun for pumping a LASER. In the Westinghouse experiment, Nichrome, Al, Cu & W (tungsten) wires were used and were exploded by electrical discharges from a bank of capacitors that is capable of an energy output of 33000 joules and up to 20000 volts. Results obtb from the work were considered encouraging] 15) H.S. Leopold, "Initiation of Explosives by Exploding Wires", NOLTR 63–159, 15 May 1963 16) Ibid, Pt 2, NOLTR 63–244, 15 May 1963 17) H.S. Leopold, "Initiation of Explosives by Exploding Wires III", NOLTR 64–2, 17 Mar 1964 18) H.S. Leopold, "Initiation of Explosives by Exploding Wires IV", NOLTR 64–61, 4 May 1964 (Effect of Wire Length on the Initiation of PETN by Exploding Wires) 19) J. Blackburn & R.J. Reithel, "Exploding Wire", 3rdProcConfExplodingWirePhenomenon, Boston, Mass (1964), 153–73 (Sweeping image photographs of the EBW initiation of PETN)

Exploding Bridge Wire Detonators. See Vol 4 of Encycl, pp D807 to D809

Exploding Bridge Wire Detonators of Reynolds Industries, Inc. Recent addts to EBW detonators include one with pigtail leads and one coaxial. Info available on these devices includes nature of the expl materials, bridgewire, connectors, firing specifications in terms of minimum energy and potential, maximum cable length, and functioning time. Time fluctuations are within 0.02 microseconds provided that the same circuit is used Ref: Reynolds Industries, Inc, 2105 Colorado Ave, Santa Monica, Calif 90404, quoted from Expls&Pyrts, Vol 2, No 7 (1969)

Exploding Bridge Wire Devices; Their Protection from Damage by Spurious RF Energy. Under the title "Skin Effect RF Bridge Filter", there is described an invention which provides
a much simplified approach to a device which
excludes current from a load. This device
can be used to protect electroexplosive
systems from damage by spurious RF energy.
The filter, which can be produced at very low
cost, is a Wheatstone bridge or lattice net-
work which uses resistive elements composed
of a metal conductor coated with a second
metal. At a predetermined frequency the fil-
ter, by utilizing the skin effect, becomes a
balanced bridge which excludes current from
a load

By suitable construction the invention
can exclude either high or low frequency
current from a load

*Refs:* 1) D.A. Schlachter, USP 3704434(1972)
2) Expls&Pyrots, Vol 6, No 4 (April 1973)
(Abtract of patent)

Exploding Bridge Wire Devices, Nondestructive Testing of. Several nondestructive test
 techniques have been developed for electro-
explosive devices. The bridgewire responds,
when pulsed with a safe level current, by
generating a characteristic heating curve.
The response is indicative of the electro-
thermal behavior of the bridgewire-explosive
interface. Bridgewires which deviate from
the characteristic heating curve have been
dissected and examined to determine the
cause of the abnormality. Deliberate faults
have been fabricated into squibs. The relation-
ship of the specific abnormality and the fault
associated with it have been demon-
strated (Ref 1, abstracted in Ref 3)

The paper of Ref 2, abstracted in Ref 3,
reports a technique that will yield insight
into the quality of EBW devices in a non-
destructive manner. By employing a self-
balancing bridge it is possible to ascertain the
electrothermal and nonlinear behavior of
the device. A sinusoidal current is passed
through the device which provides a signal in
the form of a unique Lissajous Display (See
Note, below). This display can be qualita-
tively evaluated and abnormal units can be
readily detected

*Note:* Lissajous Display are figures formed
by the locus of points, the horizontal and
vertical coordinates of which are given by
sinusoids having different frequencies, am-
plitudes or phases

*Refs:* 1) V.J. Menichelli & L.A. Rosenthal,
"Fault Determinations in Electroexplosive
Devices by Nondestructive Techniques",
Jet Propulsion Lab Rept TR 32-1553, March
15, 1972. Order as N 72-20920 from NTIS,
US Dept of Commerce, Springfield, Virginia 22151
2) L.A. Rosenthal & V.J. Menichelli, "Electro-
thermal Follow Display Apparatus for
Electroexplosive Device Testing", Jet Prop
Rept TR 32-1554, June 1, 1972. Order as
N72-21281 from NTIS 3) G. Cohn, Expls&Pyrots,
Vol 6, No 3 (1973) (Abstract of Refs 1
& 2)

**Exploding Bridge Wires Energize Laser.** See
Ref 14 under EXPLODING BRIDGE WIRE in this Vol.

Exploding Bridge Wire Initiation of Explosives.
The following NOLTR's (Naval Ordnance Lab-
oratory Technical Reports), White Oak, Maryland
20910 on "Initiation of Explosives by
Exploding Wires", are listed in Expls&Pyrots,
Vol 1, No 7(1973). They are all authored by
H.S. Leopold:

1) "Effect of Circuit Inductance on the Initia-
tion of PETN by Exploding Wires", NOLTR
63-159, May 1963 (AD 424-513) 2) "Effect
of Circuit Resistance on ....", NOLTR
63-244, May 1963 (AD 431-785) 3) "Effect
of Wire Diameter on ....", NOLTR 64-2,
March 1964 (AD 600-038) 4) "Effect of
Wire Length on ....", NOLTR 64-61, May
1964 (AD 601-990) 5) "Effect of Wire
Material on ....", NOLTR 64-146, October
1964 (AD 609-449) 6) "Further Effects
of Wire Material on ....", NOLTR 65-1,
March 1965 (AD 463-360) 7) "Effect of
Energy Termination on ....", NOLTR
65-56, June 1965 (AD 618-675) 8) "Survey
to Determine Explosives Capable of Initiation
at Moderate Voltage Levels", NOLTR 65-127,
Nov 1965 (AD 476-199) 9) "Exploratory
Studies of Explosive Initiation at High Vol-
tage Levels" (U), NOLTR 66-144(Conf),
Exploding Wire (EW). Same as Exploding Bridge Wire (EBW) or Electrically Exploding Wire (EEW)

Exploding Wire Materials. A wire exploder capable of vaporizing small wires in times less than \(10^{-7}\) sec was used to study the electrical expln of various materials & sizes in a variety of environments. Simultaneous voltage & current oscillograms with nano-second resolution were obt. These measurements were supplemented with time-resolved Kerr cell photographs of the wire at different times during an expln as well as by time-integrated spectrograms.

The description of the electrical prop of exploding wires in air prior to dwell for peak specific power levels between \(5 \times 10^{12}\) and \(2 \times 10^{14}\) watts/mole is as follows:

Wires of various elements can be classified in two phenomenological classes:

1) the low boiling point, low heat of vaporization materials, and

2) the transition elements

In silver & copper the approach to dwell commences with the onset of vaporization. The apparent resistivity during this phase is a function only of time, and the initial wire radius is independent of the rate of energy input & wire environment.

In all the materials studied, early photographs show a uniform structure for the exploding wire. A uniform illumination persists for most materials until the beginning of post-dwell conduction, although in Al shortly after expln bright spots and non-uniform regions of illumination occur.

Copper (a Class 1 material) showed no observable expansion of vapors during the phase when main sequence was followed. Tungsten, on the other hand, showed appreciable expansion of vapors after the onset of vaporization and before the end of vaporization.

For wires mounted in environments other than air, with other conditions remaining unchanged, the apparent resistivity as a function of specific energy density has the same dependence in the initial phase as in air.

Exploding Conductors. Techniques have been developed to observe & measure the rapidly varying currents and extremely high voltages of discharge systems. It was discovered that X-rays are produced under certain conditions by exploding conductors. In addn, a time history of the X-ray emission was obt which indicated that X-rays were emitted at times of the order of \(28 \times 10^{-9}\) sec after initiation of the discharge, and that radiation persisted for \(8 \times 10^{-9}\) sec.

Spectrographic studies were also made to det the temp & densities. The plasma temp and particle densities were also det by using the relative intensities of two adjacent lines of the same species and applying the Saha equation.

In addn to temp & density measurements, spectrographic investigations were made near the UV emission produced by exploding Al wires in vacuum using the W (water-dielectric) capacitor.

From the standpoint of technology, exploding wires are being used as fast-intense light sources, as fast fuses, as generators of fast shock waves, as sources of fast dense plasma for plasma propulsion & hypervelocity particle accelerators, as well as in various electronic switching & pulse shaping applications. Furthermore, the possibility of putting enough energy into a wire to initiate a thermocatalytic reaction has been under investigation from time to time.


Exploding (or Detonating) Ammunition and Explosives Destined for Destruction. Explosive materials or ammunition items which cannot be destroyed by burning or by chemical method must be destroyed by explosion (or detonation) or drowned in deep places of the ocean as far as possible from the nearest land (See Vol 3, p D28-L).


Decontamination of water Containing Dissolved Explosive Wastes is in Vol 3, p D36-L.


Alphabetical List of Destruction and Disposal Procedures for Explosives and Propellants is given in Vol 3, pp D29-R to D35-R.

In exploding (or detonating) of ammunition or explosives, the usual procedure is to place a block of TNT, Dynamite, Nitrocellulose, Starch, or Comp C3 in intimate contact with the material to destroy and to detonate the block with a Blasting Cap, ignited either electrically or by means of a Bickford Fuse (also known as Miner's Safety Fuse). In the first case, the electric wires should be of sufficient length to allow the personnel to retire behind a barricade out of danger; in the case of Bickford Fuse its length should be such that the time of burning is sufficient to allow the personnel to retire behind a barricade or other suitable protection before the explosion takes place.

In exploding of ammunition or explosives, the following safety regulations should be observed:

1) If the destruction of materials takes place on an artillery range or similar site which is far away from magazines or other buildings, the material may be piled directly on the ground, covered with a 2-ft layer of earth, and exploded.

2) If the site of destruction is located closer than 800 yards to buildings, a pit, trench or bombproof shelter should be used and the material should be covered with a thick layer of logs, earth, etc, to limit the range of fragments.

3) The number of units that may be safely destroyed at one time must be carefully determined by starting with a limited number until the maximum that can be destroyed without damage to surrounding property, is determined.

4) After each blast, or in case of a misfire, the personnel should not approach the site until a period of at least 30 minutes has elapsed. A careful search should be made for any unexploded material, and if any be found, it should be mixed with the material to be exploded at a later time.

5) Materials awaiting destruction should be stored at a distance of not less than 500 ft, preferably in small piles located about 100 ft apart. This is to prevent accidental ignition or explosion from fragments, burning embers, or grass fires.
6) It is most important that personnel conducting these operations be properly trained. To send untrained personnel on such jobs would be criminal.

7) Ample fire-fighting equipment should be available in the immediate vicinity and the ground should be wet down at the close of each day's operation.

3) Dept of the Army Technical Manual, TM 9-1300-203 (April 1967), Chapter 6, pp 6-1 to 6-2 (Destruction of ammo to prevent enemy use)

Exploration for Natural Gas and Oil by Seismic Method (Geophysical Prospecting). It is known that the earth has been segregated by geological processes into layers of various density and elastic behavior. It is also known that natural gas and oil are formed in sedimentary areas and in the normal course of events they gradually migrate towards the surface of the earth until they are trapped by some dense, relatively impermeable structure or by irregularities in layering, such as faults and folds which may serve as reservoirs for accumulation of gas or oil. In the early days of oil prospecting, the surface indications, geological studies and "hunches" provided the only bases on which the oil-men could select a drill-site. Since about 1923, however, increasing use has been made of subsurface maps obtained by geophysical methods. The most important of these methods is seismic exploration (or prospecting). It is based on the fact that a sudden shock, such as that caused by an explosion sends our seismic energy in all directions. This energy is divided when it reaches the boundaries of geological formations of different acoustic impedances (the density multiplied by the sound velocity), while some of the energy returns to the surface where it is detected by extremely sensitive electromechanical instruments, known as geophones. When these instruments are placed near the source of the noise, so as to record the energy travelling in an essentially vertical path, the technique is known as the reflection method. When the geophones are extended over large distances from the source, as compared to the depth of interest, the technique is known as the refraction method. In this case the seismic energy is propagated over an essentially horizontal path in a high-velocity material overlain by a low velocity material. The vibrations returning to the surface are picked up by geophones. They convert the ground motion into electricity which is amplified and recorded by an oscillograph and magnetic tape recorder. The oscillogram, commonly known as the record, permits an immediate inspection to determine if the shot were properly recorded. The magnetic tape record is subsequently analyzed at a data processing center where geological maps are prepared (Ref 2, pp 351-52)

More detailed description of the refraction method is given on pp 353-54 and of reflection method on p 354

According to Meyer (Ref 1, p 401), expls used in seismic exploration must be especially water-resistant, very powerful to give expl waves which will be readily detectable over large areas within the limits of the instruments used, and have a high detonation velocity. Blasting Gelatin and Gelatin Dynamites have been used for their power. For detonators it is required that they not only fire the charges but the exact instant of detonation of the charge must also be known. In using an Electric Blasting Cap, there is some short lag between closing the electric circuit and detonation of the charge; in other methods the delay is even greater. This problem, known as that of the time lag, can be solved by studying characteristics of carefully standardized Electric Caps and by some other methods. At the time of publication of Ref 1 (1943), Hercules Electric Caps were
said to have a time lag of 0.0047 seconds when fired singly at 1.5 amperes with a maximum deviation of 17% and an average deviation of 6%. Acctg to the curve showing average firing time versus current for the DuPont "SSS" Seismograph Electric Blasting Caps (See Ref 2, p 363), the time lag at 1.5 amperes current is about 2.5 milliseconds (0.00025 seconds). Explosives recommended by the DuPont & Co include: Seismograph 60% "High-Velocity" Gelatin, "Nitramon" WW, "Nitramon" WW-EL, "Nitramon" S, "Nitramon" S-EL, "Nitramite" WW, "Nitramite" WW-EL, "Seismogel"  A, "Seismex" and "Seismex" PW (Ref 2, pp 358–62).


**Explorer Series of Artificial Earth Satellites.**

This series consisting of several satellites was sponsored in 1956 by the US Army Ballistics Agency and later in conjunction with the National Aeronautics and Space Administration (NASA). Other scientific, engineering and academic institutions assisted. Work began on the program in April 1956, and by the end of January 1958, Explorer 1 was lifted into orbit. It was the USA’s first and the world’s third artificial satellite to be successfully orbited. Of the seven satellites sponsored before 1960, five were successfully launched: Explorer 1, 3, 4, 6 and 7.

The first five satellites were very similar: cylindrical in shape, length approx 6 ft, 6 inches, diam 6 inches, pay load 30.8 lbs, instruments 11 lbs, perigee attained approx 225 miles, apogee 1575 miles. The carrier vehicle, the Juno 1. Explorer 6 was spheroidal in shape with 4 solar cells mounted on protruding paddles or vanes which extended 3 ft out from the main body. Length of the satellite was 2 ft, 42 inches, diam 26 inches, pay load 142 lbs, perigee 156 miles, apogee 26360 miles. Due to the size and weight, the carrier vehicle Thor-Able 3, Explorer 7 had a shape of two joined truncated cones. Its length was 2.5 ft, diam 30 inches, pay load 70 lbs, perigee attained 346.6 miles, apogee 15945 miles. The carrier vehicle was Juno 2.

The purpose of the series was to accumulate scientific data, such as inside, outside and skin temperatures; density, distribution and momentum of micro-meteorites, cosmic-ray intensity energy and intensity of corpuscular radiations, X-radiation, the extent of the earth’s radiation belt, map the earth’s magnetic field, etc. **Note 1:** Perigee is the point in the orbit of a satellite of the earth that is nearest to the earth. **Note 2:** Apogee is the point in the orbit of a satellite of the earth at the greatest distance from the center of the earth.


**Exploseur électrique.** French for Electric Exploder

**Explosibility and Flammability of Explosives, Propellants and Pyrotechnic Compositions.**

See "Detonability and Flammability of Explosives, Propellants and Pyrotechnic Compositions" in Vol 4 of Encycl, pp D211-R to D213-R and also "Detonability of Propellants" in Vol 3, p D103-L.

Explosif(s) Belgian and French Explosive(s), whereas the word “explosive” in an adjective

Explosifs à l’aluminium. Fr for Aluminized Explosives. Several Fr formulations are listed in Vol 1 of Encycl under ALUMINUM CONTAINING EXPLOSIVES, on p A146-L. Examination in 1902 by CSE (Commission des Substances Explosives) showed that some of these expls, as, for example, Formula 226 (p A146-L), were more powerful than PA (Picric Acid). More recently (1948 & 1950), Médard (p A148-L) determined the properties of the following Fr aluminized explosives: Nn°30, Nn°31, Nn°32, Nn°33, 63—CSE—1949, Sofranex A and Sevrane A n°1

Explosifs d’amorçage. Fr for Priming or Initiating Explosives. No information at our disposal about compns of such Fr expls

Explosif amylocé. See Amide (Explosif) in Vol 1 of Encycl, p A168-L

Explosif antigrisou. See Antigrisou (Explosif) in Vol 1, p A466-R

Explosifs antigrisouteux. French industrial explosives authorized for use in fiery coal mines, because when used under prescribed conditions they do not ignite mixtures of methane-air-coal dust. They may be subdivided into explosifs couche (qv) and explosifs roche (qv)

Corresponding explosives are known in Belgium as explosifs SGP (sécurité-grisou-poussiére), and in the USA as permissible explosives. In Great Britain they are called permitted explosives, and are to be distinguished from authorized explosives which conform to certain conditions with respect to safety in handling, in transport, etc. Both kinds, permissible and authorized, are safety explosives, known in France as explosifs de sûreté and in Germany as Sicherheitssprengstoffe. The Ger name for permissible expls is Schlagwettersichere Sprengstoffe and are distinguished from Handhabungssichere Sprengstoffe, the term applied to those which are safe to handle. In Russia, permissible expls are known as Antigrisutniyi or Predokhranitel’niyi Vzryuchatiye Veschestva, in Spanish speaking countries as explosivos de seguridad contra el grisú and in Italy as esplosivi antigrisutosi

Refs: 1) Marshall 2(1917), 582 2) Davis (1943), 347 3) Pérez Ara (1945), 250 4) Belgrano (1952), 165 5) Yaremko & Svetlov (1957), 113

Explosifs brisants (or détonants). Fr for High Explosives

Explosifs C or Explosifs du type C. See C (Explosifs) in Vol 2, p C1-L

Explosifs chlorotés, also known as Explosifs O or Explosifs du type OC. See Chlorate Cheddites in Vol 2, pp C155 to C159

Explosifs couche. Fr expls with temp of expln below 1500°, which are permitted for use in coal layers of fiery coal mines. For example, Grisou-naphthalite couche contains AN 95 & TNNaphthalene 5%, while Grisou-dynamite couche contains NG 12.0, collodion cotton 0.5 & AN 87.5% (Ref 1). Sartorius and Kreyenhult (Ref 2) reported Explosifs couche contg NaCl 15 to 25% and Explosifs couche améliorés contg 44 to 58% NaCl (Comp with Explosifs roche)

Refs: 1) Davis (1943), 350–51 2) R. Sartorius & A. Kreyenhult, MP 38, 90 (1956)

Explosif "D". Fr high explosive: RDX 85 & TNT 15%. Ref: C. Fauquignon et al., 4th ONR Symposium of Detonation (1965), p 45-R

Explosifs DD. See DD Explosifs in Vol 3 of Encycl, p D19-L

Explosifs déflagrants. Fr for Low Explosives (LE)

Explosifs de démolition. Fr for Demolition Explosives

Explosifs détonants (or brisants). Fr for High Explosives (HE)

Explosif E. Swiss explosive, received at Picatinny Arsenal from Britain and examined by Livingston. Its compn was found to be AN 75, Nitroguanidine 19 & hydrated magnesium nitrate. It could be cast at 111–135° but was of low brisance. Ref: S. Livingston, PATR 907 (1938)

Explosifs Favier. See FAVIER EXPLOSIVES in Vol 6 of Encycl


Explosif Formule 226. See Vol 1 of Encycl, p A146-L

Explosifs fulminants. Fulminating Explosives such as MF

Explosif Le Maréchal (Poudre Le Maréchal): K chlorate 84 & stearic acid 16%. Ref: Gody (1907), 266

Explosifs de mine. Fr for Mining (or Commercial) Explosives

Recent progress and actual tendencies in the field of mining explosives in France was discussed by L. Mèdard in MP 32, 209–24 (1950). Fr "nonpermissible" mining expls are listed in Vol 3 of Encycl, p C438-L & R. Fr "permissible" coal-mining expls are listed on pp C450-R & C451-L

Explosif MDN (or MDn). A Fr HE consisting of Dinitroanaphthalene 1 & PA 4 parts. It had a lower mp (105–109°) than PA (120–22°) and was less sensitive to shock. It was used for cast-loading projectiles. Ref: Davis (1943), p 157

Explosif MDPC. Fr HE contg PA 55, Dinitrophenol 35 & Trinitromethylresol 10%. Its low mp (80–90°) permitted its use for cast-loading projectiles. Ref: Davis (1943), p 166–67

Explosif MMN. A Fr HE contg PA 70 & Mononitronaphthalene 30%, fused together under water. It was used as a bursting chge in drop bombs during WWI. Ref: Davis (1943), p 157

Explosif MMTC. A Fr yel HE consisting of PA 55, TNT 35 & Dinitrophenol 10%. Because of its low mp (80–90°), it can be easily cast loaded. It was used as a bursting chge for shells. Ref: Davis (1943), p 166

Explosif Muller. Older Belg grisoutite, manuf at Baelen-sur-Néthe: NG 45, Mg sulfate 45 & woodflour 9%. Ref: Gody (1907), 357 & 705

Explosifs N or du type N, also known as Explosifs nitratés (Nitrate Explosives). Fr mining expls contg AN. They can be non-permissible and permissible. Accdg to Marshall, Vol 1 (1917), 389, they are also known as Grisoumites. They can be either couche (See Explosifs couche) or roche (See Explosifs roche)

Examples of older Explosifs N are listed
Explosifs N (nitrate’s) à l’aluminium (Nitrate Explosives with Aluminum). See under ALUMINUM CONTAINING EXPLOSIVES in Vol 1, pp A146-L & A148-L

Explosif NDNT: AN 85, TNT 5 & DNNaphthalene 10%. This explosive, as well as Explosifs: NT (AN 70 & TNT 30%), NTN (AN 80 & TNNaphthalene 20%), N2TN (AN 50, Na nitrate 30 & TNNaphthalene 20%) and NX (AN 77 & TNNxylene 23%) were used in France during WWI for loading 75mm shells in lieu of Schneiderite, known as Explosif Sc
Ref: Davis (1943), 367

Explosifs à la nitrocellulose. In addition to using straight slightly wet Guncotton in compressed form for loading some shells and torpedo warheads (as was done in France to a limited extent during WWI and in Russia as late as WWI), the French also used the so-called potenite, which consisted of CP1 (NC of 13% N) & K nitrate 50%. They also used the mélanges de Sarau et Vieille, which contd CP1 40 & AN 60%. Another mixture proposed by the same scientists contd CP1 58 & K chlorate 42% but was too dangerous to use. The Belgians used a mixture consisting of CP1 32 & Ba nitrate 48%
Ref: Pepin Lehalleur (1935), 354

Explosifs N à la pentolite (Nitrate Explosives with Pentolite). The following expls were developed in 1942 by Lécorché and their manuf began in 1943:

\[
\begin{align*}
\text{Nn}^\circ\text{20}: & \quad \text{AN 78.2, Pentolite (20/80) 18.3} & \text{& woodflour 3.5%; its power by CUP 119.5} \quad \text{(PA 100)} \\
\text{Nn}^\circ\text{21}: & \quad \text{AN 75.4 & Pentolite (80/20) 24.6% (CUP 123.5)} \\
\end{align*}
\]
Ref: L. Médard, MP 32, 214-15 (1950)

Explosifs NR, Explosifs du type NR or Explosifs nitratés résistant à l'eau (Nitrate Explosives Resistant to Water). In order to render some AN mining expls resistant to water and to prevent caking of AN particles, Médard (Ref 1) and LeRoux (Ref 2), suggested coating of expl mixtures with small amts (0.5–1.0%) of Ca stearate. The use of this substance in expls was first proposed in 1896 by G. Roth of Germany and later patented by duPont & Co (USP 2048050 of 1934). The Commission des Substances Explosives (CSE) studied not only the use of stearate (as waterproofing agent), but also the abietate, naphthenate, resinate, alginite, etc but came to the conclusion that Ca stearate gave the best results. It was found, however, inefficient for aluminized expls (Ref 1)

The following samples prep'd at LaPouderie d’Esquerdes were examined by LeRoux (Ref 2):

\[
\begin{align*}
\text{Nn}^\circ\text{0R}: & \quad \text{AN 79, TNT 20 & Ca stearate 1%} \quad \text{Power by CUP 117 (TNT 100)} \\
\text{Nn}^\circ\text{1CR}: & \quad \text{AN 87.5, DNNaphthalene 11.5 & Ca stearate 1%. CUP 109} \\
\text{Nn}^\circ\text{7R}: & \quad \text{AN 76, DNN 7, woodmeal 1, NaCl 15} \quad \text{& Ca stearate 1% (CUP 84)} \\
\text{Nn}^\circ\text{21R}: & \quad \text{AN 75.5, Pentolite (20/80) 23.5} \quad \text{& Ca stearate 1%. CUP 121} \\
\text{Nn}^\circ\text{30R}: & \quad \text{AN 81, TNT 9.5, Al 8.5 & Ca stearate 1%. CUP 135} \\
\text{Nn}^\circ\text{31R}: & \quad \text{AN 79, Pentolite (20/80) 11.5, Al 8.5 & Ca stearate 1%. CUP 134} \\
\end{align*}
\]
Ref: L. Médard, MP 32, 216-17 (1950).
2) A. LeRoux, MP 33, 265-82 (1951)
Explosifs O or OC (Explosifs du type O).
Chedite-type expls authorized in France before WWII for use in coal mines. They existed in several formulations as can be seen from Tables 2, 3 & 5 of Vol 2 of Encycl, pp C157 & C159

Explosif O2: K chloride 79, DNT 15, MNNaphthalene 1 & castor oil 5%
Ref: Bamett(1919), 111

Explosifs O3 or Prométhéo were authorized at the end of the 19th century in France under the name of explosives On°3 for blasting purposes. They also were authorized in Italy. They were developed in 1897 in Russia by Ievlet and were considered as Sprengel-type Explosives. Explosifs On°3 were prepared by dipping cartridges of a compressed oxidizing mixture of K chloride 80–95 & Mn dioxide 20–5% into a liquid prep by mixing nitrobenzene, turpentine and naphtha in the proportions 50/20/30 or 60/15/25. The most serious disadvantage of these expls was an irregularity in behavior resulting from the circumstance that different cartridges absorbed different quantities of the combustible oil, generally between 8 & 13% and that the absorption was uneven and sometimes caused incomplete detonation

Explosif O4 or Explosif P: K chloride 90 & paraffin 10%; deton vel 3565m/sec at d 1.45
Ref: Bamett(1919), 111

Explosif O5: Na chloride 79, DNT 16 & castor oil 5%
Ref: Bamett(1919), 111

Explosif On°6B Minélite B: Expl mixture consisting of K chloride 90, paraffin 7 & vaseline 3% used by the French during WWII in grenades and mines. A similar expl contg Na chloride 90, instead of K chloride, was used in grenades and trench mortar bombs
Note: Minélite A contd K chloride 90, paraffin 7 & heavy Petroleum oil 3%, while Minélite C contd K chloride 89, paraffin 5, vaseline 4 & pitch 2%
Refs: 1) Davis (1943), 361  2) Perez Ara (1945), 210

Explosif P (potasse). Same as Explosif O4, listed above
Note: Acqcd to Vandoni, MP 22, 149 (1926), the same term was applied to mixture of Amm perchlorate 61.5, Na nitrate 30.0 & paraffin 8.5%

Explosifs perchloratés. See Perchlorate Cheddites in Table 5, C159 of Vol 2. It includes among other mixtures the French Cheddites I, II & III and Sevranites n°1 and n°2. One Belgian Chedite (known as Yonkite), one British (known as Blastine), one Swedish (known as Territ), one Ger military Chedite and three German Perchloratites are also included

Explosifs plastiques. The following French plastic expls are listed in Vol 3, p C438: Explosif du type n°18, Nobélite, Sevranite No 1, Sevranite No 2, Sofranex A and Tolamite. See also L. Médard, MP 32, 217–19 (1950)

Explosifs de Poudres. Fr expls and propellants patented after WWII by the État Français, FrP 971644 (1951) & CA 46, 9311 (1952) include mixtures of combustibles, such as: NGu (Nitroguanidine), HNDPhA (Hexanitro-
diphenylamine) and 9-Oxo-2,4,5,7-tetranitrothiodiphenylamine with oxidizers, such as nitrates, chlorates or perchlorates. For example, mixtures of NGu 53 with Amm perchlorate 47% and mixts of NGu 56 with K nitrate 44% were claimed to possess high temperatures of deflagration and be suitable for use in weapons operating at high temperatures or for oil seismic prospecting at great depth.

**Explosifs rocch.** Fr expls with temp of expln beewn 1500° and 1900°, which are permitted for use in rock layers of fiery coal mines. For example, Grisodynamite rocch contains NG 29.0, collodion cotton 1.0 & AN 70.0%, while Grisodynamite rocch salpeâtre contains NG 29.0, collodion cotton 1.0, K nitrate 5.0 & AN 65.0%.

**Refs:** Davis (1943), 351

**Explosif S (soude):** Na chloride 89 & paraffin 11%

**Refs:** 1) Davis (1943), 361 2) Pérez Ara (1945), 210

**Explosif Sc.** Fr designation of Schneiderite, which was prep'd accdg to Davis (Ref 1) by incorporating 7 parts of AN and 1 part of DNNaphthalene in a wheel mill, and was loaded by compression. It was used by the French during WWII for loading small- and medium-sized HE shells, especially 75mm.

**Pérez Ara (Ref 2) gives compn of Schneiderite as AN 88, DNNaphthalene 11 & resin 1%**

**Refs:** 1) Davis (1943), 367 2) Pérez Ara (1945), 240

**Explosifs SGP (Explosifs sécuritâ, grisou-poussière).** Accdg to Marshall (Ref 2), "explosifs SGP" stand for Belgian term "explosifs sûr-grisou-poussière" and signify explosives safe (sûr) to be used in coal mines cong firedamp (grisou) and dust (poussière). Testing of commercial expls intended for use Belgian fiery coal mines was formerly con-ductted at Frameries gallery, near Mons, by the method briefly described in Ref 2, p 585, and more fully in Ref 1, pp 710–11. The current gallery is located at Pâturages and the tests are briefly described in Ref 3, pp C710–R & C711–L. If no ignition of firedamp-dust mixture takes place in the gallery with maximum charge ("charge limite") of 31 oz, the expl is qualified as SGP, but max chge allowed underground is only 28 oz.


**Explosifs ou silicium.** Under this term are known expl formulations contg pulverized silicon, developed in 1950 by the laboratories of the Commission des Substances Explosives. They were "explosif n°78–CSE–1950" and "explosif n°88–CSE–1950". Their compositions and properties are given in Vol 3 of Encycl, p 571–L

**Explosifs de Sprengel.** Dr H. Sprengel, the inventor of the mercury pump, took out in 1871 patents for a series of mining expls to be made by mixing oxidizing substances with combustibles in such proportions that their oxygen balance to CO₂ should be close to zero. The essential feature was that the two constituents were to be mixed together on the spot just before the blasting operation and the mixture was to be exploded by a fulminate detonator. As oxidizing agents Sprengel recommended fuming nitric acid and K chlorate; as combustibles many substances, among them nitrobenzene, nitrinaphthalene, petroleum, carbon bisulfide and PA. Expls using nitric acid did not find much use because they were corrosive and dangerous to handle; and if the acid came in contact with a detonator, a premature explosion could take place (Ref 3, p 43).

**Gody (Ref 2) listed several mixtures using nitric acid, among them HNO₃ 71.9 & NBenz 28.1%; HNO₃ 60 & DN Benz 40%; and mixture known as Oxonite: HNO₃ 41.7 & PA 58.3%**

More successful than Sprengel nitric acid expls, were his mixtures of K chlorate with
liquid combustible materials. Gody (Ref 2) listed one of such mixtures as K chlorate 90, carbon bisulphide 9 & PA 1% and stated that it was very brisant.

The American S.R. Divine patented in 1880's several such mixtures, among them Rack-a-rock used on Oct 10, 1885 for the great blasting operation of Hell Gate in New York Harbor (Ref 3, p 43). These expls are described in Vol 5 of Encycl, p D1525-L & R.

Many Sprengel expls based on chlorates are described under CHEDDITES OR STREETITES in Vol 2 of Encycl, pp C156-R to C159, Tables 1, 2, 3 & 4. Most of the formulations listed in these tables are French.

One of the Sprengel-type expls was developed in 1897 in Russia by Ievler and authorized in France for blasting purposes under the name of Explosif On°3(qv) or Prométhée.

Acdg to Marshall (Ref 3, p 43) there are considerable advantages to transporting separately two inert ingredients, as oxidizers and combustibles of Sprengel expls, but against this must be put the difficulty and inconvenience of mixing the constituents in the right proportions on the spot. If made up beforehand, the cartridges are dangerously sensitive and become more so on keeping. In case of K chlorate expls, the chlorate is made up into porous cartridges which are transported to the spot of blasting, where they are dipped into liquid combustibles just before use. These expls were not allowed in Great Britain, as this dipping operation is considered to constitute a process of manufacture, and consequently could only be carried out in a duly licensed factory (Ref 3, p 378).

More detailed description of Sprengel expls is given by Davis (Ref 5, pp 353-60), who lists among Sprengel or Sprengel type explosives: Oxinite (See above), Hellhoffite (1879): HNO₃ 72 & N-Benz 28%; Rack-a-rock (See above); Explosif On° 3 (or Prométhée) (See above); Fielder’s—a liquid contg N-Benz 80 & turpentine 20 parts absorbed by a mixture of K chlorate 70 & K permanganate 30 parts; Kirsanov’s—a mixture of turpentine 90 & phenol 10 parts absorbed by a mixture of K chlorate 80 & Mn dioxide 20%; Panclastites of Turpin are described below under Explosifs de Turpin; Anilite (See Vol 1, pp A442-R & A443-L); Oxyliguits prep’d by impregnating porous cartridges of combustibles with liquid oxygen or liquid air, just before blasting operation; and chlorate and perchlorate explosives (See also Ref 4, pp 11-12 Refs: 1) Daniel (1902), 746-60 2) Gody (1907), 709-11 3) Marshall (1917), pp 43 & 378-83 4) Stettbacher (1933), pp 11-12 & 309 5) Davis (1943), 353-60.

Explosifs de sûreté (Safety Explosives). French and Belgian term for expls "safe to handle and to transport", but it does not mean that such expls are safe for use in coal mines with atmosphere contg firedamp and coal dust. For expls safe to use in such coal mines, the term "explosifs anti-grisetouts" is applied. This distinction between the terms was recommended by Belg Prof Watteyne and adopted by the Congrès de Chimie Appliquée à Rome in 1906 (Refs 1a & 2).

Older "explosifs de sûreté" are described by Daniel (Ref 1).

A current definition of "explosifs de sûreté" is given in the French "Règlement pour le Transport des Matières Dangereuses" as follows: An "explosif de sûreté" is an explosive which does not present any danger of explosion in mass either by combustion or by shocks (impacts) of the highest intensity which may be produced in the course of transportation and handling (See Ref 6, p 213, footnote).

The term "explosifs de sûreté" corresponds to Amer and British "Safety Explosives"; German "Handhabungssichere Sprengstoffe" (Refs 3 & 4); Russian "Besopasnyije v Obrashchenii Vzryvcharyje Vyeschhestva" (Ref 5); Italian "Esplosivi di sicurezza" (Ref 2) and Spanish "Explosivos de seguridad" (Ref 4).


Note: It is stated on pp 213-14 & 223 of Médard that after WWII, the explosif de sûreté...
Explosifs et Poudres de Turpin. Accord to Daniel (Ref 1, p 777), the following expls and propellants were invented by Eugène Turpin beginning in 1881: Borotine (See Vol 2 of Encycl, p B250-R); Celluloidine (See Vol 2, p C95-R); Duplexite (See Vol 5, p D1570-L); Fluorines (Permissible expls patented in 1888: 1) NG 37.5, kieselguhr or rhodonite 12.5 & Ca fluoride 50.0%; 2) K chloride or nitrate 35, Ca fluoride 50 & DNBz 15% (Daniel, p 302); Mélinite [Explosion mixture of PA 70 & NC (previously dissolved in acetone) 30%, patented in 1890's for use in torpedoes and demolition charges (See Daniel, pp 434-36)] (The term mélinite is also applied to straight PA)]; Oxydine [Safety expl patented by Turpin in 1888. It was a mixture of Dynamite No 1 50 with ZnO or ZnS 50%. Dynamite No 1 consisted of NG 75 & kieselguhr 25% (Daniel, 594)]; Ponclastites [Liquid, Sprengel-type expls patented by Turpin in 1881. They consisted of nitrogen tetroxide (which is a less corrosive oxidizer than strong nitric acid) and a liquid combustible substance, such as carbon bisulfide in proportion 1:1.81 which corresponds to equation:

\[ \text{CS}_2 + 3\text{NO}_2 \rightarrow \text{CO}_2 + 2\text{SO}_2 + 3\text{N.} \]

Other liquid combustibles, such as petroleum, benzene, toluene, etc., were proposed, but Turpin preferred carbon bisulfide. Ponclastites were successfully used in Belgium as military demolition explosives and in Germany they were tried for loading projectiles. For this two glass containers with thin walls were used. One was filled with NO₂ and the other with CO₂. They were placed inside the projectile, one on top of the other, and in order to prevent premature breakage, several rubber cubes were inserted between the walls of projectiles and glass containers. The glasses broke by shock on departure of projectile from the gun barrel and this caused the mixing of two ingredients. Explosion of mixture took place on arrival to target (See Daniel, pp 596-98); Ponclastites-guhr [Solid expls patented by Turpin in 1882. They consisted of Ponclastites absorbed by solid, porous materials, such as kieselguhr. They were less powerful than corresponding liquid expls (See Daniel, p 598)]; Picromic Acid and its salts were patented by Turpin in 1887 & 1888 for use in expl mixtures, listed in Daniel, p 615; Picric Acid (PA) and Picrotes were patented in 1885 by Turpin for use in some expl mixtures. This was not new, because PA was already used as early as 1867 by Borlinetto (See Vol 2 of Encycl, p B250-R); Progressite (Powder patented by Turpin in 1888: Ba nitrate 65, Amm picrate 15, DNBz 10, coal tar 6 & brown charcoal 4%. It could be ignited without the use of a detonator) (See Daniel, p 651)

Note: Other Progressites listed in Daniel, p 652 were safety expls which were not invented by Turpin. They will be described under P's

Pyrodialytes. Under this term Turpin patented, beginning in 1881, chlorate expls using tar (goudron) as a combustible. In order to neutralize acids present in tar, 2 to 10% of Na carbonate or bicarbonate was incorporated. They are described by Daniel on pp 661 to 663

Following Table Ex1 lists nonpermissible Pyrodialytes (Compositions are given in parts because they do not always add up to 100)

<table>
<thead>
<tr>
<th>Components</th>
<th>Extra</th>
<th>Forte</th>
<th>Lente</th>
<th>Lente</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n00</td>
<td>n01</td>
<td>n02</td>
<td>n03</td>
</tr>
<tr>
<td>KCIO₄</td>
<td>88</td>
<td>80</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>NaNO₃</td>
<td>-</td>
<td>-</td>
<td>48</td>
<td>-</td>
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<tr>
<td>KNO₃</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Tar (Goudron)</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Charcoal</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>K or NH₄ bi-carbonate</td>
<td>2-3</td>
<td>4</td>
<td>4-5</td>
<td>4-5</td>
</tr>
</tbody>
</table>
Table Ex2 lists some perchlorate Pyrodialytes patented in 1898, (in %)

| Components, % |  
|---------------|---|
| KClO₄         | 80 60  |
| NH₄ClO₄       |    85 75 60 50 40 |
| KClO₃         |    15  |
| Tar           | 10 10 15 10 10 10  |
| NH₄TNCre-sylate | 10  |
| NH₄TPNhe-nate |   30 10 10  |
| AmmTNBen-zaate |     |
| GuN*          |    40  |
| NH₄MnO₄       |    5  |

* Gu = Guanidine

Other "explosifs de Turpin", listed in Daniel include:

Turpin (Poudres dites à double effet). These expls patented in 1881 & 1883 contained K chloride about 80 & coal tar about 20 with some charcoal and may be considered as precurors of "Pyrodialytes". It was allowed to replace half of chloride by K or Pb nitrate or to replace 10% of chloride by K permanganate. Some of the formulations contd silicium or kieselguhr if tar were too fluid (pp 777-778) Turpin's Explosives patented in 1887 contd as main ingredients chloro-, bromo-, or iodonitrates of coal tar without inorganic oxidizers. They could be initiated by a MF detonator or by a cartridge of Dynamite (p 778) Turpin's Explosive, patented in 1883 contg Ba nitrate 60, DNBz 15 & MNPhenol 25% could be initiated by a safety fuse (p 778) Turpin Explosives with Percarbonates, especially with K₂C₂O₆, were suggested because they evolve on decomp of oxygen and can explode on being initiated by a very strong detonator, even if they are not mixed with other substances. Their use in admixture with Pyrodialytes was recommended (p 778) Turpin's Propellant, described by Gody (Addn Ref A, p 641) patented in 1888, was prepd by incorporating into NC jelly some camphor and paraffin which served for slowing down the rate of burning. After passing thru a macaroni press and cutting into desirable sizes, the grains were dried and packed into cartridges

Turpin's Explosive, described by Colver (Addn Ref B) was patented in 1885 for filling HE shells. It was prepd by mixing powdered PA with small amounts of collodion cotton, grease, or aqueous gum arabic and forming into blocks of the desired shape and size.

Note: Accdg to Stettbacher (Addn Ref C, 15), Turpin discovered in 1885 that PA (Picric Acid) can easily be detonated by means of a MF cap and for this reason can serve as pressed or cast chge for filling HE's shells. It was used for this purpose in France since 1886 under the name of Mélinite and in GB-UK since 1888 under the name of Lyddite and then later in Japan as Shimose. Although PA was known for more than 100 years before Turpin's discovery, it was not used straight but always in mixtures, such as of Borellet and of Désignolle invented in 1867 (See Vol 2 of Encycl, p B250-R and Vol 3, p D90)

Addn Refs for Explosifs de Turpin:
A) Gody (1907), 266, 270, 551-52 & 641  
B) Colver (1918), 14  
C) Stettbacher (1933), 12, 15 & 182  
D) Pepin Lehalleuer (1935), 245, 255, 344 & 359  
E) Davis (1943), 166  
F) Pérez Ara (1945), 211, 226, 228 & 513  
G) Giua, VI (1959), 403 (Panclastitti)

EXPLOSION. See under DETONATION, EXPLOSION AND EXPLOSIVES, Introduction and Definitions in Vol 4 of Encycl, pp D217 to D223-L (11 refs)

Various items described in Vol 4, pp D225 to D732 under Detonation should also be applied to Explosion

Explosion of Ammoniacal Silver Compounds and Their Solutions are described in Vol 1 of Encycl, pp A305 & A306-L with 8 refs.

An abstract of a recent "Safety Dept Report on Ammoniacal Silver Nitrate Explosion" by
R.R. Whitman, Oct 1968 is published in Manufacturing Chemist Assoc, March 1969, Accident Case History No 1554. Also, an abstract by J.A. Conklin is found in Explos.-Pyrotec 3(4)(1970). Whitman's rept discusses in depth the potential hazard of ammoniacal silver salt solutions. The solns of Ag salts in Amm hydroxide are occasionally encountered in synthetic inorganic chemistry and, in addition, are frequently employed as "Tollen's reagent" for det of the presence of aldehydes. Note: Tollen's reagent is prepd by dissolving 10g of silver nitrate in 60ml concd ammonia & 40ml water; a small quantity of this soln is mixed immediately before adding to the sample in a test tube with an equal vol of 10% aq NaOH soln. The fomation after a while of a silver mirror in a test tube indicates the presence of aldehydes.

Whitman's rept described several cases where laboratory prep of ammoniacal Ag salt solns led to explns. In addn, quotations from the literature sources demonstrate the variety of warnings (or lack of the same) that have been given for Ag salt-ammonia systems. The majority of workers discussed in this rept appear to favor the theory that Ag₃N (silver nitride or "fulminating silver") is the explosive species involved. Precipitation of a dark material prior to expln was reptd in several of the cases cited by the author.

Preventive measures and a list of literature references are included in the report.

For addnl info on Fulminating Silver, see Vol 6 of this Encycl.

**Explosion Autocatalytic.** See Vol 4 of Encycl, pp D225-R to D226-R

**Explosion, Break Character of.** See Vol 4, p D225-R

**Explosion, Breaking Theory of Carl.** See Vol 4, p D227 to D228


All of the weldments prepd for this investigation were carefully ground smooth in accordance with procedures reqd for 100% X-ray inspection of pressure vessels.

Test conditions previously established for other 1-inch quenched & tempered steel weldments of the same strength level as Y-steel (a proprietary low alloy steel contg less than 1% each of Ni, Cr, Mo etc) were followed in the expln bulge test of Y-steel weldments. Thus, 20 x 20 inch weldments were explosion loaded using 7-lb Pentolite chgs placed at 15-inch offset distance from the test sample. Generally, expln bulge testing is discontinued after 3 successive shots if failure is not developeed or after that shot which results in a visible indication of failure. For this test program, it was recognized that microfissures were present in the weld metal as received. Accordingly, several of the Y-steel weldments were tested with an addtl explosive shot even though crack indications were obtd on the second shot.

Explosion bulge tests were conducted at 30°, 0°, and -50° F. For "general service" application (pressure vessels, tanker or cargo ships) it was deemed that Y-steel weldments would perform satisfactorily at all ambient temps. It was also clear also that this material is not suitable for applications based on "military service" loading conditions (submarine hulls reqd to withstand expl action of depth charges).

**Explosion, Chain Reactions.** See Vol 4, p D229

**Explosion of Coal Dust and/or Firedamp.** See under Coal Mine Explosions and Fires in Vol 3, pp C360-R to C367-R
Explosion of Coal Gas. See Firedamp Explosion under Coal Mine Explosions and Fires in Vol 3, pp C360-R to C367-R

Explosion in Coal Mines. See previous item

Explosion of Combustible Substance and Transition from Combustion to Detonation. See A.F. Belyaev, ZhPriklKhim 23, 432-39 (1950) & CA 47, 2987 (1953) and also in Vol 4 of Encycl under Detonation (and Explosion) Development (Transition from Burning (Combustion) or Deflagration, pp D245-R to D252-R (35 refs)


Following is an abbreviated translation by Mr Cyrus G. Dunkle, formerly of Picatinny Arsenal and now residing at 2500 Holman Ave, Silver Spring, Maryland 20910:

It is known that initiation of solid TNT explosion cannot be caused by local heating to high temperature, unless the material contains some bubbles of gas, such as air, Ar, etc. This means that the presence of gas bubbles is of importance, although they do not seem to take part in the chemical reaction. The luminescence of these gases on shock heating plays a decisive role. By 2-color pyrometry with electronic amplification the temp exceeded 5000°K during the 1st few μs of the 20-30-μ sec process, far above what could be due to the reaction heat. Adiabatic compression by the shock waves heats the trapped gases intensely, and their radiation is largely absorbed in the explosive. For further clarification, the change in the entire radiation spectrum with time was observed, and micro-densitometric measurements were made at points corresponding to 1, 5, 7.5, and 200μs after initiation in cast and in powdered TNT. At 1st the detonation spectrum is that of extremely hot gas (500-6000°K) under high pressure. Later, up to 75μsec, the spectrum is that of a high-pressure gas and a solid body together. The luminosity increases up to 75μsec and then decreases. At this point most of the reaction is completed and the material, up to this time at high pressure and high d, has absorbed most of its own radiation.

Thermodynamic treatment of the processes occurring through the shock waves traversing the explosive showed that the greater the ratio of the energy evolved on the break-up of the explosive mol (E_d) to the activation energy (E_a), the less energetic the shock needed to initiate an explosion. If the ratio is low, as in many explosives, good initiation can be insured by suitable porosity and introduction of gas bubbles.

Radiation energy also plays a role, hertofoe overlooked, in the initiation of fire-damp by mine explosives. The IR absorption spectra of explosion-suppressing additives and the intensity/time relationship of the inflammation were recorded. The best suppressors were those of moderate B, P, or F content. They were effective even if 8-10% less were used than of the more usual materials, and did not impair either the stability or the performance of the explosive.

The ignitability of fire-damp by ignition cartridges was reduced by the presence of CO and moisture in the mine gases but increased by the presence of combustible gases and by heating. Raising of pressure at 500-800 torr had no effect. An industrial Dynamite-type explosive giving better fire-damp-safety was developed contg limestone powd instead of the usual rock salt or AN. The storage, stability, or explosive performance were not affected. The limestone powd wth sp surface of 3000cm²/g absorbed heat not only by its own temp rise, but also by thermal dissocon. Its lack of hygroscopicity is another advantage. Whereas the brisance of Dynamite contg limestone and AN decreases about 20% on damp storage for 500 hr, that of Dynamite contg limestone alone,
actually showed a small improvement, 10%, which was not diminished on normal storage for 1-2 yr. When like ants of limestone powd, rock salt, and AN were added to Dynamite batches, that contg limestone had the greatest brisance. Andreev attributed this effect to suppression by the limestone of the formation of active intermediate explosion products which initiate explosion of CH₄/air mixts. Also, their formation decreases the brisance.

In researches for prediction, prevention, and control of spontaneous mine fires, 0 absorption on exposed coal surfaces in certain proportions, along with moistening, had an adverse effect and thus a fire barrier not thick enough set into motion air streams capable of building up ignition centers. In quasi-adiabatic oxidn, researches with measurements at contg functional groups of the bituminous-coal mol (OH, COOH, CO and CH₃O), as also the effects of their concns on O-absorbability and the tendency toward self-ignition, were studied. With a coding system developed by the "contact period" or "induction period" detn method, bituminous and brown coals can be characterized from the viewpoint of their tendencies toward oxidn and toward self-ignition.


Explosion of Composite Explosives. See Vol 4, pp D232-R

Explosion of Composite Propellants. See Vol 4, p D238

Explosion of Condensed Explosives. See Vol 4, pp D238-R to D242-L

Explosion, Craters in. See Vol 4, p D242-R

Explosion, Damage Caused by. See Vol 4, p D245-L

Explosion, Dangers (Hazards) of. See Vol 4, pp D245-L and D366 & D367

Explosion, Dangers in Chemical Plants by. See Vol 4, p D245-L

Explosion, Dark Waves in. See Vol 4, p D245-L

Explosion, Decay in. See Vol 4, p D245-L

Explosion, Development from Combustion or Deflagration. See DETONATION (AND EXPLOSION) DEVELOPMENT (TRANSITION) FROM BURNING (COMBUSTION) OR DEFLAGRATION in Vol 4, p D245-R to D252-R (35 refs)

Explosion and Fire Suppression Techniques. Pressure-time relation for aircraft fuel mixts show that max press requires a stoichiometric mixt as well as max pressure before explosion. Rate of pressure rise is dependent on flame speed, vessel size, and nature of the ignition source. Three types of detectors are used to control such expls. Two are visual detectors, one detects rate of pressure use. After detection, exph is suppressed within msec by expln of a capsule contg 2-8ml per gal of CBF₃, CBr₂F₂, CH₂BrCl, CCl₄, or CH₂Br.

Ref: G. Grabowski, SAE Trans 63, 803–8 (1955) & CA 49, 16435 (1955)

Explosion Disasters, Prevention of. The most useful terms for evaluating the hazards of various combustible-oxidant
systems are the limits of flammability and min spontaneous ignition temp. A review of terms used in gas explosions technology is followed by a discussion of many ways of preventing disasters

Explosion, Distant Effect of. See Vol 4, p D252-R

Explosions of Dusts. See Vol 5, pp D1578-R to D1579-R

Explosion of Dusts, Mists and Vapors. See Vol 4, pp D253-L to D255-R

Explosion, Dynamics of. See Vol 4, pp D255-R to D256-L

Explosion, Effects of Blast and Shock Waves on Structures. See Vol 4, pp D256 & D257

Explosion, Effects of Inert Components on. Detailed measurements and calculations are made of the energy transferred to chemically inert “fillers” by physical processes such as heat conduction and compression during the detonation of TNT. Further evidence was obtained that the temp coeff of the processes controlling reaction rates in the detn is small

Explosion, Effects of Inert Gases on the Explosion Delimitation of Methane-Air Mixtures. The origin, development and end of explns of methane-air mixts (I) are discussed according to the relation of the explosion nos. Formulas are given for the calcn of the expln delimitation of I under the influence of inert gases. Mathematical results are compared to Jones’ empirical results. First practical application of the new math method is also described
Ref: F. Orsak, Uhlf 5, 382–90 (1955) & CA 50, 11017–18 (1956)

Explosion, Effects of the Physical Structure and the State of Aggregation on the Detonating Capacity of Explosives. Liquid TNT detonates only if the diam of the specimen is above 32mm. TNT powder compressed to the sp gr of the liquid TNT, detonates at diam of 2.1mm or greater. Pieces of solid TNT are similar to liquid TNT. Maximum diams for liquid TNT and TNT powder are 2.3 and less than 2mm, respectively. Gas space between expl particles facilitates detn, presumably because hot gases spread the detn
Ref: A.I. Apin & V.K. Bobolev, ZhFizKhim 20, 1367–70 (1946); Engl abstract in CA 41, 3297 (1947)

Explosion, Effects Produced in Air, Earth and Water. See Vol 4, pp D257-R & D258-L

Explosion, Effects of Sheaths on Gases from. Sixteen permissible expls, 7 of which were in cartridges of 2 sizes, $\frac{1}{4} \times 8$ inches and $\frac{1}{2} \times 8$ inches. Nine different sheaths were tested at low loading densities in one application and with confinement and fireday stemming in another. Results indicate that sheathed expls do not introduce important hazards from prod of CO and in some cases amt is reduced by their use. Undesirable amt of N oxides may be produced by too great a wt ratio of sheath to expl
Ref: E.J. Murphy, USBullMines Repts Invest 4220, 57pp (1948) & CA 42, 4348 (1948)

Explosion, Electrical, Electromagnetic and Magnetic Effects Accompanying It. See Vol 4, pp D258-L to D264-L
Explosions of Electrostatic Origin in Industry. Prevention of. Explosions during electro surgery of the colon can be caused by intestinal CH₄ and(or) H₂. Expts with H₂ show introduction of CO₂ thru a smoke-aspirating sigmoidoscope at the rate of 2 l/min will inhibit the explosions

Explosions, Elements of Risk in. The elements of risk in incendiaries and expls and their prevention are discussed
Ref: A. Blandin, Rhône: A. Martez & Givors, 368pp (1952) & CA 47, 6657 (1953)

Explosion, Energy of. See Vol 4, pp D264-R to D266-R

Explosion, Enthalpy in. See Vol 4, p D265-R under Explosion, Energy of

Explosion, Enthalpy Excess in. See Vol 4, pp D267-L to D268-L

Explosion, Entropy in. See Vol 4, p D265-R under Explosion, Energy of

EXPLOSION, EQUATIONS OF STATE IN.
See Vol 4, pp D268-L to D298-R (Numerous refs)

Explosion, Expanding-Jet Theory of Jones.
See under Detonation (and Explosion), Nozzle Theory of Jones, Vol 4, pp D460-R to D461-R

Explosion, Experimental Data Interpretation of. See Vol 4, p D299-L

EXPLOSION, EXPERIMENTAL PROCEDURES. See Vol 4, pp D299-R to D346-L (Numerous refs)

Explosion Hazards from Use of Coal Dust. See Coal Dust Explosion Hazards from Its Uses on p C339-R of Vol 3

Explosions and Fires. See Fires and Explosions

Explosion, Gap Tests in. See List in Vol 4, pp D303-R & D304-L

Explosions - Gaseous, Kinetic Studies of. Flash photolysis techniques are described, the reaction products being observed in both emission and absorption with resolution times of about a μsec. Some results with C₅H₅N-O mixts photo sensitized with NO₂ are given

Explosions in Gases. See Vol 4, pp D351-L to D360-L

Explosions in Gases. Determination of Ignition Points. See Vol 4, p D360

Explosions of Gases, Vapors and Dusts. Development (Transition) from Burning (Combustion) or Deflagration. See Vol 4, pp D360-R to D363-R

Explosion in Granular Explosives. See Detonation in Granular Explosives in Vol 4, pp D365-R & D366-L

Explosion Hazards (Dangers) of. See Vol 4, pp D366 & D367 and also p D245-L
Explosion Hazard of Organic Vapors, Reduction of. A process which comprises the treatment of wood with hydrocarbon vapors at an elevated temp, after which compressed air is used to impregnate the wood with a preservative. Explos hazards are reduced by introducing steam at 10–20psi before applying the air. Steam is added in an amount equal to the partial pressure of the organic vapor in the closed space.

Ref: M. Hudson, USP 2633429 (1953) & CA 48, 5502 (1954)


EXPLOSION: HEATS OF FORMATION, COMBUSTION, DEFLAGRATION, EXPLOSION AND DETONATION. See Vol 4, pp D369-L to D384-R

Explosion, Heat Sensitization of Explosives and Memory Effect. See Detonation, Heat Sensitization of Explosives and Memory Effect on pp D367-R to D369-L of Vol 4

Explosions, High Altitude Effects. High altitude nuclear exploits have helped considerably in understanding natural radiation belts. The Argus artificial radiation belt made in 1958 gave info on the stability of particle orbits. The Starfish artificial belt made in 1962 gave quantitative info on electron lifetimes not available any other place. Below L = 1.7 the electrons have a long life and apparently are lost only by coulomb scattering on the atmosphere. Above L = 1.7 the lifetime shortens abruptly and some non-atmospheric process dominates. Synchrotron radiation & aurora were also observed after the Starfish nuclear exploit.

Ref: W.N. Hess, “The Effects of High Altitude Explosions”, National Aeronautics and Space Administration, NASA TND-2402, Sept (1964)

Explosions, History of is reviewed in the book of R. Assheton, published by the Institute of Makers of Explosives, NY (1930) See a detailed discussion of this subject under History of Explosives in Vol 7 of Encycl.

Explosions, Homogeneity by Flash Photolysis. Light emitted from flash-initiated expls of acetylene and O photo sensitized by NO_2 in a large quartz tube was studied photoelectrically. Presence of very short-lived intense emission from the diatomic radicals was confirmed. Although main part of expl is homogeneous, 2 deton waves travel a short distance to the ends of the reaction vessel. Sharp peak is caused by the impact of one of these deton waves on the vessel window nearer the spectrograph.


Explosions by Hot Wires. Ignition failures with thin nichrome wires in methane-air were due to fusion of the wire before sufficient energy had been communicated to the gas to effect ignition.

Ref: 1) H.P. Stout & E. Jones, 3rd Symp on Combustion and Flame and Expln Phen, University of Wisconsin, Madison, 329–36 (1948) & CA 46, 11624 (1952)

Explosions in Ice. Twenty-four instrumented and 106 uninstrumented blasts ranging in wt from 2.5 to 40 lbs of four types of explosives (60% Straight Gelatin, Composition C4, Atlas Coalite 7S & Atlas Coalite 5S) were detonated above, in contact with, and at various depth below ice surfaces.

These tests were conducted at the edge of the Greenland Ice Cap, near Camp Turo, during the summer of 1957. This study was designed to obtain fundamental data on producing excavations in frozen ground, on forming trenches & foxholes for troops in arctic & sub-arctic regions, and on the design of structures in an arctic or sub-arctic environment to resist damage by expls.
Under-ice direct shock pressure, air-induced under-ice shock pressure, and air-blast pressure from shallow under-ice bursts, contact bursts, and near-contact bursts were measured. The apparent crater and the true crater were measured, and the mechanics of the fracture were studied. The height to which the flyrock was thrown was measured using motion pictures, and the ground rise & venting phenomena were studied also. Sixty-six seismic records were taken.

The details of this test program are given in the Ref

Explosion by Impact. See Vol 4, p D391-R and Fig 45 on p D392

Explosion, Impetus and Available Energy of. See Vol 4, p D391-R

Explosion, Impulse in. See Vol 4, p D393-L & R. Included is definition of Imp-specific impulse employed in jet propulsion

Explosion, Impulse Effects on Solids. New method for recording is described by W.E. Bron et al, ASTM Bull 50 (TP 38), Feb 1957

Explosion, Impulse Specific. See Vol 4, p D394-L


EXPLOSION (OR DETONATION) BY INFLUENCE OR SYMPATHETIC DETONATION AND TESTS. See Vol 4, pp D395-R to D402-L (Numerous refs)

EXPLOSION (AND DETONATION), INITIATION (BIRTH), AND PROPAGATION (GROWTH OR SPREAD) IN EXPLOSIVE SUBSTANCES. See Vol 4, pp D402-L to D417-R

Explosion, Initiation and Shock Processes. See Vol 4, pp D417-R to D419-L

Explosion, Jet-Piercing Theory of. See Detonation (and Explosion), Penetration or Jet-Piercing Theory of Apin in Vol 4, pp D467-R to D470-L

Explosion at Lake Denmark Naval Ammunition Depot Located Adjacent to Picatinny Arsenal, Dover, New Jersey.

As in all walks of life, industry has its accidents & disasters. That there are not more of them is due in a large measure to safety rules and their enforcement. The risk in the manuf & handling, and in the storing of expls has been made a special study by the Institute of Makers of Explosives and others. The American Table of Distances, a result of their studies, has been incorporated in a number of states in the USA

The activities at Picatinny Arsenal have been separated to comply with safety distances and all known means are employed to safeguard workers. When accidents have occurred, it has been due to these precautions that injuries to employees and loss of material or damage to buildings have been kept to a minimum at Picatinny

The story of the Lake Denmark Explosion that levelled many buildings at Picatinny Arsenal on 10 July 1926 is well told in the "History of Explosions", published under the direction of the Institute of Makers of Explosives. Their rept reads, in part, as follows:
On July 10, 1926, there occurred a series of expls on the Lake Denmark Ammunition Depot of the United States Navy (about 3½ miles from Dover, NJ). This Depot comprised an area of 461 acres of land, partly overgrown by trees and brush. It included approx 160 buildings, 44 of which were used for the storage of high explosives, smokeless powder, projectiles, Black Powder, the remaining being store houses, industrial buildings which did not contain expls, and dwellings.

On the afternoon of July 10, 1926, there was a severe electrical storm at Lake Denmark. At about 5:15 PM lightning struck in the southwest end of the Depot, and almost immediately thereafter, black smoke was seen issuing from the northeast side of Temporary Magazine No 8. An alarm of fire was sounded and the personnel of the Depot responded immediately to the fire call, and at least one stream of water was playing on the fire when at 5:20 PM a tremendous detonation occurred at the scene of the fire.

The first expln occurred in Temporary Magazine No 8, and was followed in about 5 minutes by the expln of the contents of Temporary Store House No 9, which was about 150 ft in the clear from No 8. Enormous craters were made by the two explosions. Buildings in the immediate vicinity of Temporary Store Houses Nos 8 & 9 were ignited by embers, missiles or direct heat from the explns, and the fire spread rapidly to other magazines, store houses, and shell houses.

Temporary Store House No 8 contained:
2106 - 50 lb cast TNT depth charges, detonators removed
850 - aerial bombs, TNT center section
1800 - 300 lb depth charges, TNT middle
100 - 25 lb Navy Mark 1, loaded and plugged (aircraft); accessories for bombs in wooden boxes

Estimated total amt of expls 670000 lbs

Temporary Store House No 9 contained:
1250000 lbs Grade A flake TNT in 50-lb boxes
350000 lbs Grade A TNT stored in 100-lb boxes
150 to 160 Mark IV aircraft bombs, probably 250 lbs TNT to each bomb

Estimated total amt of expls over 160000 lbs TNT

A third series of explns occurred in Shell Store House No 22. The contents were:
40 - 14" Class B shell, loaded & fuzed
80 - 14" AP shell, loaded & fuzed
360 - Mark I bombs, each loaded with 50 lbs TNT
1000 - Mark II bombs, each loaded with 50 lbs TNT
300 to 400 - Mark III bombs, loaded with TNT
200 - Mark IV bombs, loaded with TNT
500 - Mark V bombs, loaded with TNT
10000 - 8" shell, loaded & fuzed
1000 - 5" shell, loaded & fuzed

Estimated total amount of expls in building 180000 lbs

Within 3000 ft radius of Temporary Store Houses Nos 8 & 9, everything on Lake Denmark Depot was wrecked, burned or otherwise destroyed, with a few exceptions. Beyond the 3000 ft radius, and as far as the Navy reservation (estimated under 5600 ft), all of the blgs were damaged in more or less degree by the expln, but as there were no expls or powder stored in the blgs in this area, no fires occurred.

Probably one of the outstanding matters of interest was that the following expls stored did not detonate, but burned:
2500000 lbs Explosive D stored in Temporary Store House No 11, about 500 ft away from the site of expln
300000 lbs Explosive D and 20000 lbs Picric Acid in Dry House No 1, 750 ft away from the site of expln
300000 lbs Explosive D in Dry House No 2, 300 ft from the site of expln and only 50 ft from Dry House No 1
510000 lbs TNT in bulk burned in Temporary Store House No 7

Adjoining the Lake Denmark Depot was the Picatinny Arsenal of the US Army which lay about 150 ft below the point of the hillside which was the site of Temporary Magazines Nos 8 & 9. Approximately the slope of the ground on Lake Denmark Depot continued thru the Picatinny Arsenal down to Picatinny Lake. Bordering the Lake the ground was practically level, to the west the ground rises abruptly to a higher elevation than the hills.
east of Lake Denmark Depot. The level
land of Picatinny Arsenal was fairly well
cleared, except the east end, and the west
hillside were wooded. The area occupied
by Picatinny Arsenal was approx 3 miles
long by \( \frac{3}{8} \) mile wide, and scattered over it
were the 350 or so buildings of a miscel-
laneous character, which comprised the
Arsenal

Practically all of the bldg's on PA were
placed at a lower elevation than the buildings
in which the explns occurred and, as there
were no barricades, were directly exposed to
the force of the explns, except for such pro-
tection as was afforded by trees surrounding
the location

When the explns occurred in Temporary
Store Houses Nos 8 & 9, a wave of tremendous
pressure was thrown over the Picatinny area
intensified probably by the hill back of Build-
ings 8 & 9. The wave broaden out as it
proceeded until it finally struck the hills to
the west, and how it reacted from then on is
difficult to establish, but coming or going it
spread over the entire valley causing de-
struction or damage

Eight buildings within the 1000 to 2000 ft
zone were completely demolished. Nineteen
others were wrecked or considerably damaged.
Thirty-five bldg's within the 2000 to 3000 ft
zone were partially wrecked or seriously da-
maged. Buildings within the 3000 to 4000 ft
zone were variously affected depending upon
the materials of construction, wooden frame
bldg's being completely wrecked. Substantial
bldg's outside the 4000 ft zone suffered prac-
tically no damage except broken windows &
cracked plaster. About 75 other bldg's, less
substantial, suffered some roof damage and/or
collapsed walls. Damage to outside properties
in nearby communities was limited to broken
windows, damaged roofs, and structural da-
mage to frame buildings up to \( \frac{3}{8} \) miles away

Killed and Injured. Nineteen casualties
were caused by the detonations. The greatest
loss of life occurred in the fire-fighting parties
in the vicinity of Temporary Store Houses 8 & 9.
Eleven marines and one enlisted man of the
Navy, and four commissioned officers were
ekilled at this point. Most of the men killed
were in the first fire-fighting party to arrive
at the scene, and were probably all within
300 to 500 ft of the expln

Thirty-eight officers and privates in the
Navy Marine Corps were injured. About 25
of these were with the second fire-fighting
party which, with a horse cart, had reached
a point near Store House No 1 (within 1000 ft
of Temporary Store House No 8) when the
first expln occurred. The body of a woman
was found under the ruins of a two-story
dwelling which stood about 300 ft from Tem-
porary Store Houses Nos 8 & 9. One woman
passenger in an automobile a short distance
outside the Lake Denmark gate when the
first expln occurred was so badly injured by
flying debris that she died in the hospital
later.

The Commander of the Arsenal, Major
N.F. Ramsey, and a private were at Temp-
orary Store House No 3 (about 600 ft from Tem-
porary Store House No 9) at the time of the
first expln. Both were badly shocked & in-
jured by flying debris, but managed to remain
on duty in the upper end of the Lake Denmark
Depot most of the night following the disaster.
An officer, First Lieutenant George W. Bott
Jr, US Army, was killed in the Beater House
(Building No 385) at Picatinny by being
exposed when the building collapsed. This
bldg was located about 1500 ft away from the
first expln

Citations for bravery were awarded the
following personnel of Picatinny Arsenal for
their heroism at the time of the Lake Denmark
disaster. Receiving the Soldiers' Medal for
heroism were:

Major Herman H. Zornig
Captain Joel G. Holmes
Captain John P. Harris
Technical Sergeant Christian J. Vogt, all
of the Ordnance Dept;

US Army
Mr E. Williams
Mr I. Yamin
Mr T.E. James, all civilian employees
Major Augustus L.L. Baker, Marine Corps
and contract surgeon for Picatinny Arsenal
Sgt. Archie L. Downey, Finance Dept., PA and
Major Norman F. Ramsey, Ordnance Dept.,
Commanding Officer at Picatinny Arsenal

The New Picatinny. Immediately after
the Lake Denmark catastrophe, which did ter-
tific damage to the Arsenal 10 July 1926, no
building escaping entirely and some being
completely destroyed, the Chief of Ordnance,
then Major General C.C. Williams, appointed
a Board of Officers to appraise the damage
and to make recommendations as to action
that should be taken. This Board recommended
not only that the Arsenal be rebuilt, but that
all land be purchased to enlarge and im-
prove certain portions of it. Congress in
session in the fall of 1926 approved the re-
building of the Arsenal and, in December 1927,
appropriated $230,000 for this purpose.
The “Old Picatinny” had been a gradual
development of many years. In laying out the
“New Picatinny”, the reservation was divided
into geographical areas, into which were
placed the various activities depending upon
their character. The separation of divisions
was as follows:

1) manufacturing activities where powders
& expls are handled

2) storage areas in which powders & expls
are housed

3) manufacturing activities where non-
hazardous materials are handled, and where
administrative & engineering functions are
accomplished.

The report concluded that Picatinny is not
just another Army Post, nor is it simply another
explosives plant that has gotten back onto its
feet after a blow. It is both of these and more
because it is the very essence of our entire
national defense scheme. It is the Ammunition
Arsenal of the nation, the design & develop-
ment of artillery ammunition for the Army being
the responsibility of Picatinny.

Refs: 1) Dr. Kausch, SS 21, 210 (1926) (Das
Explosionsunlück im Lake Denmark Naval
Ammunition Depot) 2) H.S. Deck, “Safety
in Explosive Plants”, Army Ordn 7, 33–37
(1927) 3) Anon, “Heroes of Picatinny
Disaster Honored”, Army Ordn 8, 145 (1927)
8, 380–81 (1928) 5) Colonel J.K. Crain,

“The New Picatinny”, Army Ordn 9, 328–29
(1929) 6) Captain J.A. Rogers Jr., “The
History of Picatinny Arsenal”, Dover, NJ
(31 March 1931), Chapter IX, “Safety and
the Lake Denmark Explosion”, pp 72–91

Explosion, Lateral Dispersion (Expansion)
and Lateral Loss-in. See Vol 4, pp D421–R
to D423–L.

Explosion, Lateral Rarefraction Wave. See
Vol 4, p D364–R under Detonation, Geometrical
Model Theory of Cook.

Explosion, Light (Flame) Accompanying It.
See Detonation (and Explosion) Luminosity
(Luminescence) Produced on in Vol 4, pp
D425–L to D436–L (21 refs)

Explosion Limits in Condensed Explosives.
See Vol 4, p D424–L & R

Explosion Limits Determination from a Unified
Thermal and Chain Theory. In the paper of
Gray & Yang (Ref 1), a mathematical model
was proposed to unify the chain and thermal
mechanisms of explosion. It was shown that
the trajectories in the phase plane of the
coupled energy and radical concentration
equations of an explosive system will give
the time-dependent behavior of the system
when the initial temperature and radical con-
centration are given. In the 2nd paper of the
same investigators (Ref 2), a general equation
for explosion limits (P–T relation) is derived
from a unified thermal and chain theory and
from this equation, the criteria of explosion
limits for either the pure chain or pure thermal
theory can be deduced. For detailed discus-
sion see Refs

69, 2747 (1965) 2) C.H. Yang & B.F. Gray,
“The Determination of Explosion Limits from
a Unified Thermal and Chain Theory”, 11th-
SympCombust (1967), 1099–1106

Explosion, Luminosity (Luminescence) Produced on. See Vol 4, pp D425-L to D434-L

Explosion, Mechanical Effects of. See Vol 4, p D441-L

Explosion, Mechanisms of. See Vol 4, p D441-L & R

Explosion in Medium of Variable Density. See Vol 4, p D441-R

Explosion, Memory Effect. See Vol 4, p D368-L & R, under Detonation, Heat Sensitization of Explosives and Memory Effect

Explosion, Mikhail' son-Rayleigh Straight Line in. See Rayleigh-Mikhail'son Line on p D354-L, Fig A and equation 9 of Vol 4


Explosions in Mines from Al, Mg or Steel Sparks. See H. Schulze-Rhonhof, RevInd-Minérale 39, 276–90 (1957) & CA 51, 13353 (1957)

Explosions in Mines, Review. Some researches on explosions in mines after WWII and a review of progress in Belgium, France, Great Britain and the USA are given by H. F. Coward, TransInstMiningEngrs (London) 105, 228–41 (1946) & CA 40, 6259 (1946)

Explosion in Mixing House of a Fireworks Plant. An unusual explosion demolished a mixing house while two building wings remained in tact. Construction consisted of stone walls (1m thick) and a light roof. Cause was believed to be spontaneous combustion
Ref: E. Banik, Explosivstoffe 1956, 190

Explosions in Narrow Tubes, Selfacceleration of Spark-Ignited. When a CH₄–O mixt in a tube is ignited by a spark, the flame travels at the normal speed and then accelerates. In a long tube detonation may then be set up, while in a short tube the speed decreases as the end of the tube is approached. Exptl evidence suggests that initial acceleration is due to the change from a spherical to a cylindrical flame front. Expansion of hot gases then pushes the flame front down the tube, the distance traveled by the flame being proportional to the cube of the time. If gas mixt has low burning velocity, the flame will eventually travel at a lower constant speed, which is equal to the product of the burning velocity and the expansion ratio. Rapidly burning flames, however, will give rise to a shock wave which will accelerate the flame and may lead to detonation

Explosion, Nitrogen Reaction in. Apin et al (Ref) investigated reactions of RDX, LA & Hydrazine Azide produced on heating with powdered B, Be, Al, Mg & Zr. It was found that heat of detonation was higher than when the expls were heated alone. This was because B, Be, Al, etc interact on heating with nitrogen of the expls with formation of
nitriles, such as BN, Be₃N₂, AlN, Mg₃N₂ & Zr₃N₄ which released additional heat

Explosion, Nozzle Theory of Jones. See Vol 4, pp D460-R to D461-R

Explosions, Nuclear (or Atomic). See Atomic (or Nuclear) Explosion in Vol 1, p A501-R and Addnl Refs in Vol 4, p D461-R

Explosion-Operated Tool for driving steel pins or bolts into masonry, concrete or steel was proposed by H. Behrend, USP 2835894 (1958)

Explosion Parameters and Characteristics. See Vol 4, pp D463-L to D464-R

Explosion, Particle Size Effect in. See Detonation, Particle Size Effect in. See Vol 4, pp D465-L to D466-L

Explosion, Penetrating Jet Theory of Apin. See Vol 4, pp D467-R to D470-L

Explosion, Phenomena Accompanying It. See Vol 4, p D471-L & R

Explosion Phenomenology. Accdg to Dr VanDolah (Ref) exlps are generalized as a result of a rapid release of pressure without regard for its source. They may include a confined thermal exphin, a confined deflagration, a detonation, or simply pressurized gas. Each of these sources is examined in broad terms and some basic similarities of the physical processes are suggested

Explosion Physics. The cited Ref deals mathematically with the cumulative effect of shaped charges and the jets formed from metal linings of such chge
effects in the local action of the exlps. This effect is obtained by using charges which have a cavity on one of the ends - a cumulative cavity. If such a chge is initiated from the opposite end, then the expl effect in the direction of the cavity axis is found to be much greater than if ordinary charges are used. It was established experimentally that if the surface of a cumulative cavity is covered with a relatively thin metal facing, then the armor-piercing action of the cumulative chge is increased many times

Explosion, Physics of. G.I. Pokrovskii in “FizikaVzryvya” (Physics of Explosion), Moscow (1955) (See Engl abstract by G.K. Kudravez, Major, USAF, OTIA 1450, Available at PicArsn Library as No U63039) gave a discussion on an electrical explosion such as caused by a ball of lightning. Such a ball usually originates when lightning strikes some obstacle. In such case there appears a blindingly brilliant fiery ball which is easily carried by wind and which emits a unique hissing sound and is apparently saturated with certain internal movement. If this travelling ball meets any obstacle that retards this internal movement, a violent explosion takes place. This is accompanied by evolution of much heat and gases
V.A. Belakon, who studied at Physico-Technical Institute, proposed the theoretical explanation of the phenomenon described by
Pokrovskii and in abstract of Maj Kudravetz

The particles of gases formed during a
lightning ball expln, as well as in ordinary
explo., carry considerable electric charges.
In the expansion of these gases, the fluxes
of their particles move, as a rule, irregularly.
Streams of gases carrying one charge may fly
considerably forward, while mass of gases
with opposite charge may lag behind. This
results in the appearance of the electro-
magnetic field alternating in space and in
the emission to all sides of a powerful, but
very short-lived, electromagnetic impulse.

Explosion, Polytropic Curve and Polytropic
Low. See Vol 4, pp D474-R & D475-L

Explosion of Powdery Explosive Charges.
See Vol 4, pp D475-L to D476-L

Explosion Power or Strength. See Vol 4, pp
D476-L to D479-R

EXPLOSION, PREMATURE

Premature Explosions of Projectiles (Éclatements
prématurés des projectiles — in French) (In
collaboration with N.D. Baron of ADED, Pica-
tinny Arsenal).

Premature explosions of projectiles insidethe cannon may be due to many causes
but, due to the fact that anything tangible
bearing on the cause is blown to pieces, an
investigation is very difficult. It is very rare
for anything to be found among the exploded
fragments of the projectile or gun that will
throw definite light on the probable cause of
a premature. Consequently, when the cause
of a particular premature explosion is investi-
gated, it is usually necessary to consider
all the different possible causes and then
from the evidence at hand to deduce the most
probable cause in the case.

According to Major C.M. Steese, Ordi-
nance Officer at Fort Sill, USA, in any par-
ticular projectile there are about 36 distinct
and different components and it is possible
for any one of them to cause a premature

Following is a list of some of the causes
of premature:
1) Some defect in the barrel of a cannon which
would cause slowing down of the projectile
or cause a sudden increase in the speed of
it. For instance, if the rifling of the barrel
is damaged or is not smooth in spots, the
projectile might suddenly stop or slow down
and if the resulting impact is sufficiently
great, the bursting charge will explode. If
the fuze is aimed by inertia, detonation will
be complete, but if the fuze is not aimed the
detonation will be incomplete. More acci-
dents result from the use of new guns than
from older ones and more from howitzers
than from guns.

Note A. The reason new guns might be the
cause of more accidents than ones slightly
used may be explained by the fact that the
bore of new guns is not very smooth.

Note B. One of the reasons why there are
more accidents with howitzers than with
guns is that howitzers use faster propellants.
This means that the initial speed of burning
is greater and the maximum pressure is
reached in a much shorter period. If there
is a defect in a barrel near the breech, then
the impact will be greater in the case of a
howitzer than in the case of a gun.

If a barrel had been damaged previously
by a small incomplete detonation, it would
have one or several sections with enlarged
diameter. When a projectile hits such a
spot, it becomes disengaged from the rifling
and suddenly gains speed. If the charge
does not explode from this, it is sure to
when the projectile hits the rifling of the
narrow section of the barrel.

Defects in the metal of a barrel, such as
cavities etc., might cause the bursting of a
cannon by pressure of the propellant gases,
even though the projectile did not explode.

2) Some defects in the construction of a
projectile, such as weak metal, presence of
flaws, cracks etc. For instance, if the steel
had not been properly annealed, the projec-
tile might break or crack inside the barrel
and the propellant gases would ignite the
bursting charge. The charge might also be
ignited if the tail fuze were not properly
assembled.
3) Some defects in the bursting charge of a projectile, such as cavitation, exudation, etc., If a cavity is in the rear section of a projectile, the firing causes "setback" of the charge. If the cavity is in the forward section, there is danger that the shell will not explode even on striking the target because the fuze and booster might become separated from the bursting charge.

4) Some defect in construction of the fuze or of the booster might cause a premature but such cases are comparatively rare. If the fuze or booster detonates it causes complete detonation of the bursting charge.

5) If the cartridge case is too short, in the case of fixed ammunition, then the projectile does not reach the rifling. When the propellant is ignited, the gases push the projectile forward very rapidly and as soon as it reaches the rifling, a momentary slow down or a complete stop might take place. As result of this sudden change in velocity, a premature might occur.

6) If the propellant is very fast burning, the push on the projectile might be so sudden and great that it might cause a premature.

7) If the propellant is very irregularly burning, which might be caused by nonhomenogenity, the projectile will move in a jerky fashion, which might result in a premature.

\[Note.\] According to Refs 1 & 2, more premature occur with guns of larger than caliber 75mm than with those of 75mm or below. No explanation of this is given.

8) Worn gun tubes may be responsible for premature functioning of shells in that the fuze may be arched and activated by the erratic movement of the projectile in the weapon. The erratic movement of the projectile is caused by the worn rifling not properly engraving the rotating band of the shell.

9) Some American shells loaded with 50/50 Pentolite prematured and it was believed that the cause was exudation thus the closure at the base of the shell and that the exudate set up an explosive train which was subsequently ignited by the propellant when the gun was fired. When similar shells were later tested, it was shown that heating above the melting point of Pentolite (170°F) caused exudation and leakage of the exudate thru the closure at the base of the shell. Leakage also occurred at the forward end of the projectile thru the crimp between the hemispherical liner and shell body into the cavity beneath the fuze. When similar shells were subjected to a "cycling treatment", alternating 16 hours at 160°F and 8 hours at -65°F, exudate leaked from some shells, while in others a gummy material exuded from the base plug within 3 days. On storing at 149°F for 66 days, no exudation occurred, but the Tetryl pellet of the booster became cemented to the bursting charge by material which exuded from the Pentolite (Ref 4)

Refs: 1) A. Niblack, Field Artillery Journal 1928 (March-April), pp 145-50 (Prematures in the USA) 2) E. Dunin-Marcinkiewicz, MémArtillerFr 14, 155-74 (1935) (Sur les éclatement dans l'âme des bouches à feu); Translated from PrzeglądArtillerijski 1930, No 4


An AA projectile gave a bore premature which burst a gun killing most of the crew. About 6000 similar projectiles were carefully examined for defects but nothing suspicious could be found. About ten years later it was found that the base of some of these projectiles contained tiny perforations and it is possible that hot propellant gases penetrated inside the shell when it was fired.

When shells with artificially perforated bases were fired experimentally, premature were obtained.

b) 40mm loading accidents. Occasional premature explosions took place when 40mm shells were "catapulted" into the guns by the loading mechanisms and some personnel were killed and injured by the blowbacks. Extensive investigation revealed that the primer mixture occasionally broke up from shocks and vibrations in handling and ship ment and sifted out in such a way as to render the primers supersensitive.
c) Bore premature due to loose or missing tracers. During WWII, there were a very small number of bore premature among the enormous number of 5" AA rounds that were fired. As no cause could be determined, the fuze was replaced by another type but an occasional premature still occurred. Only after 4 years of extensive investigation was it found that premature were not caused by faulty fuses but by insecurely attached tracers. Experimental firings showed that if a tracer becomes loose and is detached, the propellant gases might enter the cavity from the tracer and then break thru the wall of the fuze, thus reaching the filler.


a) G.E. Rogers, "Premature of Round, Shell HE Mk II in 37mm Model 1916", PATR 207 (April 1932)

b) V.R. Reed, "Investigation of the Cause of Prematures in Ballistic Tests of M39A2 Point Detonating Fuzes", PATR 698 (May 1936)

c) C.J. Bain, "Premature of 155mm HE Shell, Mk III" PATR 805 (March 1937)

d) D.R. Beeman, "Investigation to Determine Cause of Prematures in Firing 37mm Ammunition, Lot 1075–22 at Fort Lewis", PATR 883 (Feb 1938)

e) D.R. Beeman, "Investigation of premature of 37mm Ammunition, Lot PEM 12536–1 at Pueblo, Colorado", PATR 920 (Sept 1938)

f) D.R. Beeman, "Premature Functioning of 37mm T2 HE Shell, Cast TNT Loaded with T30 PD Fuze, Lot E621–1", PATR 939 (Dec 1938)

g) D.R. Cameron, "Examination of 1000 3" AA Shell from Ammunition Lot 2724–6", PATR 1099 (July 1941)

h) R.W. Scharf, "Examination of 1138 3" AA Shell M42 from Ammunition Lot 2724–6", PATR 1109 (Aug 1941)

i) D.R. Cameron, "Examination of 1000 3" AA Shell from Ammunition Lot 2724–6", PATR 1099 (Aug 1941)

j) R.W. Scharf, "Examination and Loading of 3" AA M42 Shell with Defective Bases, Lot 2292", PATR 1120 (Oct 1941)

k) F.H. Vogel, "Examination of 155mm Shell, Lot 1–7993–22, Received from Wolf Creek Ordnance Plant", PATR 1173 (June 1942)

l) F.H. Vogel, "Examination of 75mm Mk 1 Shell, Lot NOD 5340–12, Received from the Nansemond Ordnance Depot", PATR 1199 (Sept 1942)

m) V.R. Reed, "37mm Mk II Practice Shell Investigation of Premature Functioning", PATR 1244 (Feb 1943)

n) F.H. Vogel, "Examination of 10 Each 155mm Mk 1 HE Loaded Shell, Lot DOD-25112–13", PATR 1373 (Dec 1943)

o) F.R. Benson, "Premature Explosions of 150-lb GP T1 Bombs", PATR 1537 (June 1945)

p) A.L. Dorfman, "Investigation of Malfunctions with T43–T47 Colored Smoke Aircraft Signals", PATR 1573 (Dec 1945)

q) L. Jablansky, "Investigation of Segregation in Composition B", PATR 2019 (April 1954)

t) G. Demittrick, "Investigation of Malfunctioning of 4.2 Inch Mortar Ammunition", PATR 2049 (Aug 1954)

s) L. Jablansky, "Heat Study of Composition B-Loaded 155mm M101 HE Shell", PATR 2103 (Dec 1954)

t) S.J. Lowell, "Investigation of Prematures in 75mm T50E2 Shell!", PATR 2104 (Jan 1955)

u) I.S. Kintish, "Effect of a Hot Weapon on Composition B-Loaded 105mm M1 HE Shell!", PATR 2131 (Jan 1955)

w) J. Davis, "Unsteady Temperature Distribution in a Shell Wall!", PATR 2140 (Feb 1955)

x) S.J. Lowell, "Study of Grit and Exudate as Possible Causes of 75mm T50E2 Shell Prematures!", PATR 2168 (April 1955)

y) L. Jablansky, "Laboratory Scale Test Device to Determine Sensitivity of Explosives to Initiation by Setback Pressure!", PATR 2235 (Sept 1955)

z) S.J. Lowell, "Firing Safety of Production Lots of Composition B-Loaded 75mm T50E2 HE Shell!", PATR 2236 (Sept 1955)
aa) S.J. Lowell & E.A. Skettini, "Investigation of the Safety of Firing Composition B-Loaded 155mm M101 HE Shell", PATR 2329 (May 1956)

bb) S.D. Stein & S.J. Lowell, "Study of Exudation as a Possible Cause of 75mm T50E2 Shell Prematures", PATR 2344 (Aug 1956)

c) S.D. Stein & S.J. Lowell, "Investigation of Prematures in 75mm T165E11 HEP-T Shell", PATR 2359 (July 1956)

d) L. Jablansky, "Factors Affecting Sensitivity of Composition B to Setback", PATR 2433 (June 1957)

e) S.D. Stein & R.G. Salamon, "Investigation of a Premature of a Composition B-Loaded 120mm T15E3 HE-T Shell", PATR 2507 (Jan 1958)

ff) S.D. Stein & M.J. Margolin, "Proposed Shell Loading Standards Based on a Statistical Study of Setback Sensitivities", PATR 2563 (Nov 1958)

gg) I.W. Stevens, "Investigation of Prematures and Deflagrations of 30mm T306E10 and T306E11 Shell", PATR 2565 (Oct 1958)

hh) S.D. Stein, "Investigation of a Premature of a Composition B-Loaded 240mm M114 Shell", PATR 2573 (Nov 1958)

Premature Firing of Rounds, or Premature Ignition of Propellants (In collaboration with N.D. Baron of ADED Picatinny Arsenal)

It sometimes happens that when bags of propellant of separate loaded ammunition are charged into a gun immediately after the previous round had been fired, a premature ignition of the charge takes place. This usually happens when one or several pieces of an incompletely burned powder bag from the previous charge remain glowing in the barrel. It has been claimed that cotton bags are usually the cause of such accidents and for that reason, powder bags in this country have usually been made of silk, now partly replaced by Nylon. On the other hand, the Russians have always used cotton bags either unmercerized or 50% mercerized (the threads running in one direction are mercerized while those running in a perpendicular direction are unmercerized). During WW II, the Germans used cylindrical casings made of double-base powder instead of bags. Such casings burned just as completely as the propellant.

In firings involving a high rate of fire, particularly with machine guns and anti-aircraft guns, automatic functioning or "cook-off" of a round left in the hot gun for a period of time is possible. This "cook-off" condition may result in either spontaneous ignition of the primer or the propellant powder.


Premature Explosions in Shooting Wells. In drilling holes thru certain shales, particularly those associated with oil and gas, the presence of areas which contained very finely divided pyrite was observed. When such areas are exposed to the atmosphere (especially if it is moist and warm), oxidation of the pyrite to the RSO4 form takes place. As this is usually accompanied by considerable evolution of heat, there is danger of a premature explosion if a blasting charge is introduced into the hole in order to shoot a well.

Refs: 1) D.F. MacDonald, US Bureau of Mines Bull 86 (1915) (Describes premature explosions in the Canal Zone) 2) D.F. MacDonald, Oil Trade J 11, 114-5 (1920) & CA 14, 2713 (1920) (Probable cause of premature explosion in shooting wells)

Explosion Pressures and Their Measurements. See Vol 4, pp D483 to D491-R and AddnRef: E.O. Genzsch, "Explosionsdruck als formgebendes Mittel" (Explosion Pressure as Form-shaping Means), Explosivstoffe 1964, 89-93 & 105-08
Explosion by Priming or Boostering. See Vol 4, p D494-L

Explosion Process, The Hypothetical Rate in the. A discussion of the hypothesis that a type of radiation plays a predominant role in the mechanism of the process of detonation of expl solids and liquids and in the burning of propiants

Explosion, Products of. See Vol 4, pp D494-R & D495-L

Explosion Propagation Thru Explosive Charges. See Vol 4, pp D497-L to D498-R

Explosion Propagation Thru Layers of Non-explosive Substances. See Vol 4, p D498-R

Explosion Properties and Blasting Action of High Explosives. Title of Chapter 11 in Cook’s book (1958), pp 265 to 282 (9 refs)

Explosion, Protection in. A review of approved electric switches, motors, meters, recorders and other gear suitable for use in areas where explosives are handled. Being spark proof, they minimize explosion hazards
Ref: H. Busch, “Die Schutzarten im Explosionssschutz” (Types of Protection in Explosion Protection), Explosivstoffe 1958, 54-9 (9 refs)

Explosion Pulping. In this process, wood chips about ⅛ inch long are fed into a battery of digesters (called guns), in which the chips are steamed gradually to a pressure of 1100 to 1200 psi and then, after holding at that pressure for about 5 secs, are released by means of a quick-opening valve into a cyclone. The explosive effect of this rapid release breaks up the wood chips into a fibrous mass
This treatment does not remove the lignin. The fibers are dark in color and very stiff. They are not used in paper manuf nor for the nitration of NC, but can be pressed into a product of extreme durability & hardness, known as “Masonite Presswood”
Ref: J.P. Casey, “Pulp and Paper”, Inter-science, NY (1949), pp 205-06

Explosion, Rarefaction Effect in Air Blast. See Vol 2, p B180-R

Explosion, Rarefaction Wave and Release Wave of E.M. Pugh. See Vol 4, pp D500-R to D502-L

Explosion Reactions; Physico-Chemical Investigations of. Heats of explosion of various chemicals were calculated from thermodynamic considerations and obtained experimentally in bomb tests
Ref: R. Dautel, Physikalisch-Chemische Untersuchung von Explosions Reaktionen, Explosivstoffe 1963, 10-18 (14 refs)

Explosion Reactions During Reduction of Fluorinated Compounds with LiAlH₄. Extreme caution should be used in reducing any fluorinated compd with LiAlH₄. Violent reactions are described involving 2 dif fluorocompds. Suggestions for safe operation include treating small amts of LiAlH₄ in ether with a small quantity of compd to be reduced, with drying and slow heating or carrying a trial reaction
Ref: W. Karo, C&EN 33, 1368(1955) & CA 49, 9278(1955)

Explosions; Relation Between Hardness, Melting Point and Sensitivity. Initiation by friction and impact of PETN is studied in the presence of the following grits: NH₄NO₃, KHSO₄, AgNO₃, Na₂Cr₂O₇, NaOAc, KNO₃,
Explosion, Resistance to. See Vol 4, pp D508-L to D510-L

Explosion Retardation. The sample-size effects of the explosion retardation of mercury and silver oxalates and fulminates are discussed.


Explosions, Review. A review of information on selected aspects of gas and vapor explosions are given by K.N. Palmer, JInstFuel 29, 293–309 (1956) & CA 50, 12481 (1956)

Explosion of S-IV All Systems Vehicles, Investigation of is described by J.B. Gayle of the National Aeronautics and Space Administration, in Technical Note TND–563, Sept 1964

Explosion of Shells and Bombs. Generally, a shell or a bomb filled with an HE (high explosive) detonates if properly initiated, leaving no residual explosive behind. The color of the smoke produced is either white, grey or black, depending on whether or not the explosive filling contains sufficient oxygen for complete combustion. If, however, the shell (or bomb) is not properly initiated, or if there is some defect in its construction or in the composition of the explosive itself, the entire charge is not consumed and the shell (or bomb) is said to "explode" instead of detonate. This is revealed by the color of the smoke which would be yellowish or brownish, more or less of the color of the explosive itself, because the smoke would contain some unconsumed (residual) explosive.


Explosion, Shock Wave in. See Vol 4, pp D530 to D542-L

Explosions in Space (Raumexplosionen, in Ger) are described in Refs


Explosion Spectra of Metals. Anderson was the first to use the "explosion" method of exciting spectral lines of a metal. He studied the flash of light emitted when a thin wire of a metal to be studied was exploded by an oscillatory discharge from a condenser charged to several thousand volts. As the atoms of the metal are subjected to a powerful stimulus very abruptly, the conditions of excitation are very much different from those prevailing in an arc of the same metal carrying a low current. Several investigators have developed this tech-
ique and have studied the explosion spectra of a number of substances.

Sawyer and Becher (Ref 2), Smith (Ref 3), Nagoaka and Futagami (Ref 4) modified the method and accumulated some data.

Venkatesha of India (Refs 5 & 6) constructed a special apparatus and studied the difference between the intensities of spectral lines excited in the fuse spectra of Ag, Al, Mg, Ti and in the corresponding low current arcs. The apparatus consisted of a Hilger E2 quartz spectrophotograph, an electric bulb with a straight vertical filament and a wire or thin strip of the metal under investigation, placed between two electrodes 4 cm apart, made from the same metal. The wire was interposed between the slit of the spectrophotograph and the lamp so that illumination from the lamp is cut out. The shadow of the wire is focused on the slit by a quartz lens of short focal length. The electrodes of the wire were connected thru a double pole switch to the leads from a battery of storage cells of total voltage 120 volts. When the switch was closed, the wire fused, emitting an intense light for a fraction of a second.

These investigators showed that more lines are shown in explosion spectra than in the arc spectra. The weak lines of arc spectra, especially those due to impurities, are shown much brighter by the new method. In many cases, traces of impurities undetectable by the arc spectrum were easily seen in the explosion spectra. The continuous spectrum was, as a rule, stronger than that obtained by the arc method.


Explosion and Combustion Spectra. See Vol 4, pp D549-L to D556-R

Explosion Spherical; Initial Behavior of.
Disturbance near source of spherical blast from a polytropic expl in a surrounding medium is analyzed. A second blast wave is the result of the breakdown of continuous gas flow in the neighborhood of a singular characteristic. For all types of expls, the 2nd shock is a 2nd order effect in terms of the square root of the time from the end of detonation. Application to PETN charges in air and water is discussed.

Explosion, Spontaneous. See Vol 4, pp D561-R to D563-R

Explosion, Stability and Instability of. See Vol 4, pp D569-L to D574-R

Explosion-State Products of Dynamites, TNT, LOX and AN Explosives. The explosive properties of various commercial and military expls are given in tabular form. The expls include TNT, Dynamite, high-AN-NON-NG, LOX and water compatible types. Such properties as heat capacity $C_v$, heat of explosion $Q$, absolute temp $T$, pressure $p$, and number of molecules/kg are given.
Ref: Cook (1958), 306-21

Explosions by Static Electricity Initiated, Demonstration of. Apparatus is described for initiating an explosion in an Et$_2$O-air-O mixture by static electricity.
Ref: D.S. Ainslie, AmerPhys 24, 408 (1956) & CA 50, 13443 (1956)

Explosion, Suppression System. Like any other protection system, an explosion suppression system is made up of three com-
Explosion (and Detonation) Temperature and Its Determination. See Vol 4, pp D583-L to D589-L and also Ignition (or Explosion) Temperature Test in Vol 1, p XVI

Explosion Temperature Determination as Conducted at Picatinny Arsenal. The method described by A. J. Clear in PATR 3278(1965), pp 7–8 with Fig 8 on p 39 is also described in Vol 4 of Encycl, pp D583 & D584

Explosion Temperature Determination by Rumpff’s Method. Automatic apparatus for detn of expln and deflagration temps of explosives and propellants is described by H. Rumpff, Explosivstoffe 1957, 113–14

Explosion, Temperature Developed on. See Vol 4, pp D589-L to D601-L


Explosion, Temperature Developed on. The relation between the temperature of explosion of a propellant and the speed of combustion at rocket pressures was discussed by P. Tavemier & C. Napoly in MP 37, 331 (1955)

Explosion (and Explosives) Terminology. Explosion has several attributes and hence can be described or defined in different ways. From the standpoint of chemistry, it is a rapid chemical process resulting in the evolution of gas and heat. To the classic physical definition of a high-pressure energy release must be added themonuclear effects. Both chemical and physical concepts must be combined to obtain a complete terminology Ref: H. Pessiak, Explosivstoffe, 1960, 23–6, 45–7

Explosion, Sympathetic or Explosion by Influence. See Vol 4, pp D395-R to D402-L

Explosion Theories for Gases. Recent developments of explosion theories were reviewed by Gray & Yang (Ref 3). The models of thermal and isothermal chain theories of explosion are mathematical idealizations constructed to characterize laboratory observations. They have yielded useful understanding of the explosion phenomenon in cases when physical conditions are consistent with these idealizations. Unfortunately, the attitude of regarding both theories as convenient models useful in particular instances has often been replaced by the outlook that "real" explosions are either chain or thermal; thus giving rise to the setting up of criteria to decide to which class a given case belongs. For example, Semenov (Ref 1) stated: "A thermal explosion must be preceded by a slow but perfectly measurable reaction. A chain explosion takes place under conditions of immeasurably slow reaction. In a thermal explosion the heat liberated by the reaction is the cause of the explosion. In a chain explosion, the evolution of heat is a consequence of the chain avalanche".

While Gray & Yang are not denying the usefulness of such ideas, they consider that too literal an application on the distinction can lead to difficulties. For this reason they tried to unify both theories and this problem is discussed in their paper. They also examined the effect of fuel consumption on thermal explosions, definition of critical conditions and the effects of vessel shapes. Finally, the relationship between thermal explosion criteria and flame theory described by Belles (Ref 2), as well as detonability limits were pointed out. Comments on the paper of Gray & Yang of Profs R.R. Baldwin & R. Ben-Aim are given on p 1061 of Ref 3


Explosion (Detonation, Deflagration and Decomposition), Thermal Theories and Thermochemistry. See Vol 4, pp D619-L to D622-L


Explosions of Ti in HNO₃ and Zr in HNO₃. Reports are given of explosions occurring when Ti test specimens were used in red fuming nitric acid. The cause of such explosions is unknown. The use of Zr in nitric acid solutions is described briefly

Ref: J.A. English et al, Corrosion 12, 658 (1956) & CA 50, 9988 (1956)
Explosion-Time Test of Double-Base Propellants. It was concluded from a large number of tests that the expln test does not measure the true stability of smokeless propels contg NG. Some propels rendered unsuitable by long heating at 78° still gave satisfactory expln tests at 134.5°. Addn of as little as 0.1% K nitrate caused a distinct lowering of expln time, but did not affect other tests. The presence of a stabilizer had no effect on the expln test. The effect of addg various inorg salts (from 1 to 4%) on propels contg NG 40, NC(3.08%N) 50.25 & DPhA 0.75% was also reported. Ref: D.R. Wiggan & E.S. Goodyear, IEC (AnaEd) 4, 77-8(1932) & CA 26, 1444(1932)

Explosion of TNT Plant at Saint Chamas, France. A detailed description and analysis of the causes of an expln on 16 Nov 1936 which caused the death of 53 persons are reported. Pb & Fe were found to produce expl substances from TNT in the presence of nitric acid which could be ignited by heat, shock, friction, or contact with concd nitric & sulfuric acids. Salts of Pb & Fe were found at the scene of the expln. Ref: A. Kovache & H. Thibon, MP 34, 369-88(1952) & CA 49, 4293(1955)

Explosion of Trinitronaphthalene Plant at Saint Chamas, France. On 4 April 1940 during manuf of Trinitronaphthalene, an expln occurred in the No 8 nitrator causing the death of 11 persons and injuring 53 others. The bldg was severely damaged. It was built in 1915 for making TNT but was transformed in 1924-25 for making Nitronaphthalenes. The bldg contained 12 nitrators of the Dusseldorf type arranged in a line. The capacity of each nitrator was 4 cubic meters, all equipped with stirrers operating at 100rpm. During the manuf process, the operator observed a normal temp, but the grains of Trinitronaphthalene became large and the temp reached 60°. Due to the formation of large agglomerates of crystals, the belt broke and the stirrer became inoperative. The lack of agitation prevented cooling of the nitrator and local heating (80°) took place accelerating the oxidation process. All of these factors prevented the nitrator from being discharged in the usual manner and contributed to the cause of explosion. Ref: Anon, MémPoudres 34, 389-95(1952) & CA 49, 4293(1955)

Explosions, Unexpected. POCl₃ Explodes in Lab. A severe and unexplained expln of a bottle contg recovered phosphorus oxychloride occurred at the Univ of Arizona chem lab. Dr L. Plummer was prepg the diacid chloride of ferrocene-1,1-dicarboxylic acid, using a mixt of PCl₃ & phosphorus oxychloride. He had just distilled (under reduced press) the oxychloride from the reaction mixt. The recovered phosphorus oxychloride was poured into a 500-ml brown bottle contg some of the compd recovered from earlier, similar reactions. Some of the recovered compd had been standing for ca 3 months. As the bottle was placed on a desk, an expln took place; the blast was forceful and was accompanied by a sharp report. Glass splinters from the bottle severely cut Dr Plummer and the POCl₃ caused severe burns. No satisfactory explanation of this expln has been found, reported Dr C. Marvel, nor was he aware of similar incidents involving POCl₃ (Ref 1)

Explosion at US Industrial Chemical Plant. An expln at the US IC, Tuscola, Ill plant which killed one man and injured 13 others was reported. Cause of the expln, which occurred in the plant’s ammonia synthesis area, was not determined. Preliminary investigation indicated the blast resulted from ignition of hydrogen gas escaping from a ruptured pipe. The control room & one compressor bldg wall were severely damaged (Ref 2)

Methyl Ethyl Ketone. Very little was left of a truck after its load of Methyl Ethyl Ketone exploded in Bromwich, near Birmingham, England. Thirty persons in nearby
houses were injured, but no one was killed. The driver had noticed smoke, parked in a vacant lot, and was away making a telephone call at the time of the blast (Ref 3).

**Explosion at Firestone Tire.** An expln at Firestone Tire’s Akron, Ohio research center killed veteran chemist Christian E. Best and injured 13 others. Damage was estimated at $1 million dollars. The blast occurred in a second-floor plastics lab and may have been caused by ignition of propylene fumes from a leaking cylinder. What ignited the volatile propylene fumes was not determined (Ref 4).

**Explosion at Olin Mathieson.** A blast in the propylene oxide-ethylene glycol area of Olin Mathieson’s Brandenburg, Ky organics plant injured 29 persons and caused an estimated $8 million dollars damage in April 1962. Olin believed that a pump relief valve failed and allowed ammonia to mix with ethylene oxide, causing a tank expln (Refs 5 & 9).

**Explosion at Pittsburgh Metal Purifying Company.** An expln & fire leveled the plant and offices of Pittsburgh Metal Purifying Co, Mars, Pa. killing 2 workers & injuring a third worker. The firm estimated damage at ca $1 million dollars. The company makes exothermic materials used in foundries & steel mills (Ref 5).

**Sinclair Oil Depot.** Expln & fire struck the Sinclair Oil depot along the Brooklyn waterfront on 10 May 1962. The fire, which was finally brought under control after 3 hrs, sent dense black smoke billowing skyward. No injuries were reported (Ref 6).

**Explosion from Chlorinated Rubber-Zinc Oxide Reaction.** An until-now undescribed exothermic reaction – that of chlorinated rubber with zinc oxide was responsible for an expln that leveled the manufg area of Dayton Chemical Products Laboratories, West Alexandria, Ohio in April 1962. The blast took place during mixing of a large batch of material including the two reactive ingredients along with other materials. Personal injuries involved only first & second degree burns which reqd only brief treatment (Ref 7).

**Olin Mathieson Plant Explosion.** The hydrazine unit at the company’s Lake Charles, La. chemical plant was extensively damaged by an expln 6 October 1962. One operator was killed and 4 other men were injured. Damage was estimated at over $1 million dollars (Ref 8).

**NOTE:** The above described Unexpected Explosions occurred in one year arbitrarily selected as 1962. No attempt was made to cover the extensive literature on this subject covering any other period of time.

See also Explosions, Uninvited in this Vol


**Explosion, Underwater.** See Vol 4, p D628-L to D629-L.

**Explosions, Uninvited.** Under the title of “Uninvited Chemical Explosions”, warning was given by the late Mr Tomlinson & Dr Audrieht (Ref 3) about hazards in preparation and handling of substances which were never previously considered as being explosive, but recently proved to be such. Among them were cited many oxygenated metal amine complexes such as Hexamine chromium (III) nitrate (Cr(NH3)6(NO3)3) and Hexamine cobalt (III) perchlorate (Co(NH3)6ClO4)3, each nearly as powerful an expl as TNT (Ref 1). (More than seventy ammine complexes are described in Vol 1 of Encycl, pp A277 to A282). Many other dangerous, but previously not considered as such comds...
and mixtures are listed in the Refs. If
dangerous properties of substances prepd
and handled in the laboratory and in the
plant would be known in advance, many ac-
cidents could be avoided by taking necessary
precautions and obeying safety rules.

A compound or a mixture containing an
appreciable amount of oxygen, along with a
significant quantity of nitrogen, should be
suspected, and it would be foolhardy to ig-
nore the potential danger of any substance
whose elemental components could undergo
exothermic recombination with formation of
very stable products. The simplest and most
accurate way to evaluate the potential hazard
of any product is to calculate its heat of de-
composition to the most stable products. This
can be done by making use of the Pauling
bond energies and the heat of formation of the
decomposition products.

Lohrop & Handrick (Ref 2) have shown
that there is a definite relationship betw heat
of decomposition and oxygen balance and
have indicated a simple method for calculat-
ing the former. The oxygen balance concept
can be used, a priori to good advantage, since
expl power reaches a maximum when OB to
CO₂ & H₂O is near zero. It is those mate-
rials, contg just sufficient oxygen in the
molecules to form H₂O, CO₂, and N₂, that
are capable of releasing the largest quanti-
ties of energy per gram and will, in general,
be most destructive.

The recombinzation of atoms from a re-
latively weakly bound state to more stable
states may also occur where two or more
components are brought together in proper
proportions, and where the energy of reaction
is such that its release is effected with great
rapidity, especially if large volumes of gas-
eous products are formed. Thus an associa-
tion of oxidant and reductant can be just as
dangerous as a single expl compd. In the
case of mixtures, however, it is the inti-
macy of contact which often determines the hazard
associated with such potentially reactive
mixtures. Decrease in particle size, with a
Corresponding increase in specific surface,
leads to a greater intimacy of contact of com-
ponents, as well to a greater probability of
reaction and to an increase of its velocity.
Such an increase of reactivity might cause a
LE(low explosive) like BkPdr to explode
instead of deflagrating and there is a poten-
tial danger in such action. Particularly
dangerous are mixtures of chlorates & chlor-
ites with organic matter, sulfur, and/or
phosphorus. Also very dangerous are mix-
tures of perchlorates with reactive metals,
such as Mg & Al. They are usually sensi-
tive to impact and to friction and often quite
unstable chemically.

All other factors remaining constant,
those reactions producing the greater vol-
umes of gases are the more dangerous, but
on the other hand, it is still necessary to con-
sider the reactivity of the systems.

Accdg to Lohrop & Handrick (Ref 2)
certain groupings when present in a molecule
can either confer upon it or enhance its expl
properties. They refer to radicals which
confer expl character directly as plosophors
and those which enhance expl power as
auxoplosive groupings. The plosophors
may lead either to powerful expls or to more
sensitive materials and include compds contg
the following groupings: -ONO₂, -NH₂NO₂,
-N₂NO₂, -NO₂, -NO₁, -N=N-, -O=O-, and
-N₂. Organic salts of perchloric, picric,
chloric, nitric, bromic, and iodic acids would
also be dangerous because of their high oxy-
gen content. Auxoplosive groups include
nitrile, oxime, and other linkages.

Among the compds which have been neg-
lected as hazardous are nitrations by means
of liquid nitrogen tetroxide (N₂O₄) of hydro-
carbons, and of its mixtures with various
organic substances. For example, a mixture
of N₂O₄, 70 & NBz 30% had, accdg to A.
Stetbacher, a deton vel above 8000m/sec,
despite its low density.

In the same connection it is pointed
out the inherent danger in the use of fuming
nitric acid for laboratory nitrations. Aniline
and such acid are used in some JATO units.

The action of alkalies on nitroparaffins
may result in formation of intermediates,
leading eventually to salts of fulminic acid.

There is also danger in handling of
strong hydrogen peroxide, of its salts, and
of their mixtures with organic materials, such as glycerin.

On pp 608 & 609 of Ref 3 are listed various dangerous mixtures of inorganic materials, while on p 609 are given 14 precautionary "how to avoid accidents"


Note: See also Explosions, Unexpected in this Vol

Explosions, Unique. An expln was caused in Zürich in 1919 during manuf of acetoacetic ester from \( \text{CH}_3\text{CO}_2\text{H} \) and \( \text{EtOH} \) by the violent catalytic activity of \( \text{NaHSO}_4 \) accidentally left in the reaction vessel. Other examples include explosions in the production of endothermic compds (phenyl azide and azodicarbonic ester). Explns from nitro compds particularly in 1920 during distillation of \( \text{o-} \) and \( \text{p-nitrotoluene} \), explns in the presence of oxygen under high pressure, and explns in the autoxidation of \( \text{a,o-diphenylethylene} \), also violent expln following treatment of oxalyl chloride or bromide with Na-K alloy (Ref 1). Explosion catastrophe at Bodio (Tessin) was assumed caused by the spontaneous decompn of addition products of \( \text{N}_2\text{O}_4 \) and unsatd benzenes, so-called nitrosates (Ref 2)


Explosion Unit Operation (See also "Explosive Disintegration"). The explosion technique has been applied successfully for the modification of substances and for separation of components, as well as for size reduction of materials. This method has been used in rubber reclaiming, wood pulping, manufacture of fiber board, pulverization of minerals and coal and finally for the prep of puffed cereals.

As an example of modification of substances may be cited the devulcanization of rubber scrap (patented by Gross, Ref 2, and the further development by H.F. Palmer). The method consisted essentially in subjecting rubber scrap to high pressure steam for a period of time sufficient to soften and impregnate the mass, and then the pressure was abruptly released. The resulting product consisted of plastic, devulcanized particles, directly suitable for further milling and compounding.

As an example of separation of components, the method patented as far back as 1911 by Anderson (Ref 1), may be mentioned. The process involved heating air-dry Indian corn to about 187° in a pressure-tight vessel, then suddenly releasing the pressure. The corn was discharged from the vessel and the hulls and germes were blown off by internal pressure.
Explosions, Unsteady. See Vol 4, p D575 under Detonation, Steady and Nonsteady State

Explosion and Its Utilization. Title of a book which presents a concise & popular exposition of the physical fundamentals of the theory of expln & its action. Great attention is paid to the latest accomplishments in the matter of explns. The author dwells in particular on one of the main problems of modern theory of expln-directed action & control of explns. The simplest designed formulas & numerical data will not only help study deeper the effect of expln, but can also be used in practical application of the acquired knowledge.


Explosions in Vacuo were discussed by C.K. Thornhill, in ARDE Report B/30/58, Nov 1958

Explosion, Velocity of. See Vol 4, pp D629-R to D640-R

Explosion Velocity in Gases. See Vol 4, pp D663-L to D666-L

EXPLOSION (AND DETONATION) WAVES. See Vol 4, pp D676-L to D682-L

Explosion, Work Capacity in. See Vol 4, p D730

EXPLOSIVE. Its definitions by various scientists: M.A. Cook, C.G. Dunkle, K.K. Andreev, F.A. Baum et al and others are given in Vol 4 of Encycl, under "DETONATION, EXPLOSION AND EXPLOSIVES", pp D217-L to D223-R

Explosive 808. A British demolition explosive made in paper-wrapped, 4 oz cartridges 3 x 1-5/8 inches. The explosive used was "Desensitized Polar Blasting Gelatine", which could be initiated by a primer.

Explosive 808 could be used for either external or internal work.

Note: Comp of "Desensitized Polar Blasting Gelatine" was not found.


Explosive 851 and Explosive 852. Plastic expls made by the Nobel Co in GB/Britain

"Explosive Accident/Incident Abstracts". It is the title for a compilation of 219 explosive incidents (each listing description, cause & preventive measures), 110 operational incidents and 38 potential incidents involving expls and other dangerous materials or operations. All reported to the ASEP (Armed Services Explosive Safety Board, Dept of Defense, Washington, DC, 20315) from September 1961 thru June 1967 by companies, government agencies and trade groups. Sample titles: "Explosion During Mixing Experimental Propellant"; "Explosion During Casting and During Operation"; "Inert Gas Leak"; "Inhalation of Hydrogen Cyanide Fumes"; "Explosion of Pyrotechnic Devices", etc. Each organization reporting its incidents to ASEP receives from it anonymous reports from all other cooperating organizations. These reports are valuable because they alert operators to hazards of which they might not have been aware. The Franklin Institute Research Laboratories have joined ASEP’s group of cooperators, and the newsletters of "Explosives and Pyrotechnics" will excerpt future accident/incident reports for the benefit of its readers.

The 6-year compilation is available as AD 660 020 from National Technical Information Service, PO Box 1553, Ravensworth, Va 22151

Ref: Gunther Cohn, Ed., Expls & Pyrots 1 (6), 1968
Explosive Actuator XE-16A was developed at NAVORD Labs to replace the Mk 1 Mod 0 actuator for use in Mk 52 drill mine. Better surveillance characteristics were obtb by using Unique Powder (a smokeless propellant of unspecified compn) as a substitute for Black Powder formerly used as the base chge. Milled normal Pb Styphnate was substituted for DDNP-Potassium Chlorate mix as the ignition chge. Several design changes to increase ruggedness were also made. Laboratory & field tests indicated that the XE-16A Actuator would be a satisfactory actuator in the Mk 52 Drill Mine

Ref: E.E. Kilmer & M.J. Falbo, NAVORD Rept 6111(1958)

Explosive Assembly and Method of Making It. The device described in USP 2541334(1951) of C.H. Carey & D.R. Walton is intended primarily for expls contg a high proportion of AN and little or no NG. In expls of this kind, as the apparent density is increased (as by hard packing), there is reduction in sensitivity to detonation and decrease in sensitivity by influence. Introduction of an auxiliary expl (booster) compressed to a lesser degree than the main charge assures complete detonation. It also permits the use of insensitive expls (as main charges) which could not be detonated by the cap alone.

Explosive Actuator, Re-chargeable. An experimental linear actuator similar to the "explosive diode" (qv) places a steel bulkhead between its donor charge (fired via detonating cord) and receptor charge (which fires an explosive, pyrotechnic or propellant). Bulkhead transmits the donor's shock wave apparently with no damage, so actuator can be re-charged and used repeatedly. Developed by North American Aviation for NASA-Houston, Product Engineering, April 8, 1968

Ref: G. Cohn, Edi, Expls&Pyrots 1(5), 1968

Explosive Area. Any area in which expls, propellants, pyrotechnics or ammunition are manufd, stored, handled, shipped, maintained, renovated, salvaged, etc is called "explosive area". This includes plant buildings and magazines. The area should be surrounded by a fence with guards stationed around it and the gates to prevent any unauthorized persons from entering the area. Within the area, precautions should be taken to guard against fire and accidents


The power producing expl assembly consists of a rigid cylindrical container (Fig Ex2); a rigid conical partition having an open base spanning said container is freely resting against one end wall of the container. This cone is extending toward the opposite end of container and has an apex angle between 60° and 120°. A booster expl fills the space below conical partition, while space above it is filled with main charge. A receptacle for a detonator element is adjacent to booster

A rather complicated method for prep such an assembly is described in the patent, but is not given here

FIG Ex2
Explosive of Audrieth. Mixture of AN 78.5–83.5, hydrazine nitrate (N₂H₄·HNO₃) 5–10, TNT 7.5, Al powder 0.5, pulverized carbon 3 & chalk 0.5%. It is claimed that hydrazine nitrate increased considerably the sensitivity and the rate of detonation of the mix.

Refs: 1) L.F. Audrieth, USP 2704706 (1955)
2) Guia, Trattato 61(1)(1959), 374-L

Explosive B & T No 21 (Victorite). A compn prep'd by mixing flour (18.8), sulfur (1.9) & KClO₃ (75.3%) in a soln of resin (4.2%) in an org solv, and then removing the solv by evaporation. This process is designed to coat the expl particles with resin, thereby waterproofing them and reducing their sensitivity. The product may also be dyed different colors. The compn was unsatisfactory for military application because of its sensitivity, hygroscopicity & low brightness.

Ref: J.D. Hopper, PATR 481(1934)

Explosive Bolts. See under Explosive Rivets

Explosive Bonding, also called Explosive Cladding. See Detaclad Process in Vol 3, pp D96-L to D97


"Explosive Bonding Gets Biggest Job Yet". Title of brief paper in C&EN 42, Aug 31, 1964, p 46. It describes achievements of DuPont in clad-plate market and the fabrication by Nooter Corp of St Louis, Mo of four chemical process vessels for Amoco, using DuPont's titanium-clad plates

Explosive Bonding, Mechanism of. An aerohydrodynamic analogy is used to construct a description of the formation of wavy interfaces during expl bonding, which is described by J.T. Kowalick & D.R. Hay in Metallurgical Transactions, Vol 2, July 1971, pp 1953–58

Ref: G. Cohn Ed, Expls&Pyrots 4(11), 1971 (Abstract)

Explosive Bonding, Nature of. Wave formation in expl bonding is viewed as a special case of the transition from laminar to a turbulent metal flow regime set up along the collision region between two metal interfaces. Employing a novel semicircular technique, dynamic parameters of the process are used to determine Reynolds numbers for dynamic metal flow. They are correlated with conditions for obtaining wavy bonded interfaces between metal, the most desirable type of bonding from the standpoint of obtg superior mechanical properties. A Reynolds number range of 0.38 to 14.7 is established as a necessary and sufficient criterion for expl bonding.


"Explosive Bonding Technique Emerging in NASA Plans". Title of the paper by Bob Ward in Metalworking News, Oct 13, 1969, p 27. Progress is reported in expl bonding of filament reinforced metallic composites for possible use in rocket and space station structures. Focus has been on lightweight composites reinforced with stainless and low carbon steel wire. NGU (Nitroguanidine) served as the driving expl in forming rods from expl compaction of a matrix of high-strength wires surrounded with powdered metals. Plates of widely varying metals
were bonded with similar procedures. Tensile strength of up to 70000 psi has been obtd with 1100-0 Al properly reinforced
Ref: Gunther Cohn, Edt, Expls & Pyrots 3 (1), 1970 (Abstract)

**Explosive Branding Iron.** A device for permanently marking animals, birds, fishes, etc required in wildlife studies on specific mortality, and fecundity rates. Total device weighs 3 pounds and the expl charges for 200 single-digit brands weigh 5 pounds. The applicator consists of a modified spear-fishing gun fitted with a pivoted rubber template which holds the brand. Branding is accomplished by setting off a piece of MDF (Mild Detonating Fuse) shaped to fit the template cavity which is a mirror image of the brand. MDF is 2 grains PETN per foot. Initiation is by a commercial percussion detonator fired by the spear-fishing gun trigger. The brand has been successfully applied to seals with no animal showing any distress.

Most of the previously available branding devices have the disadvantage of being either extremely heavy and cumbersome, or in the case of freeze-branding, the impossibility of being kept supplied in the field with the necessary cryogen. Electric branding needs a cumbersome high-voltage generator

**Explosive BTM of Fleischnich.** See BTM in Vol 2 of Encycl, p B319-R

**Explosive of Buccianelli** consists of a white precipitate obtd on adding triethanolamine soln to a soln of Pb perchlorate
Ref: E. Buccianelli, ItalP 588789 (1959) & CA 54, 6130 (1960)

**Explosive Bullets or Shell Bullets.** A brief description, including historical background is given in Vol 2, p B326, under BULLETS. There is also a brief description of "Bullets, Dumdum" on p B331-R

A more complete description of Explosive Bullets is given in this Vol, under "Explosive cartridges" and under "Explosive and Explosive Incendiary Ammunition".

**Explosive C-4 or Composition C-4**, also known as HARRISITE, was developed before 1950 at Picatinny Arsenal by K.G. Ottoson. Its prepn and props are described in Vol 3 of Encycl, p C485. C-4 was employed during the Vietnam war for blowing up captured enemy bunkers and to clear trees for helicopter landing areas, and then it was discovered by some soldiers that eating of C-4 produced a better “high” than marijuana. Unfortunately, the after effects were very bad: convulsions and kidney infections, with brain damage that could be permanent. Accdg to Lt Col A.J. Ognibane of the Army Medical Corps, the hospitals were full of soldiers who had eaten the stuff. The situation became so bad that many infantry companies were not being issued C-4 any more. The Captain had to have a special demolition expert to bring C-4 in by chopper when they needed it. Some outfits had difficulty getting needed supplies because the choppers could not land

**Explosive, Canadian.** An aqueous slurry of AN and TNT, developed by Canadian Industries Ltd in collaboration with inventors M.A. Cook and H.E. Famam has been used for open pit blasting at Iron Ore Co of Canada’s Knob Lake operations in Newfoundland. The fluid character of the material enables it to be loaded efficiently into bags or directly into the borehole without a container. Because of its high density (1.4) and good water resistance, it can be loaded
under water and performs effectively under wet conditions. Its strength is 70% of Gelatin Dynamite but it is considerably less sensitive to initiation. It requires a 6-oz booster of Pentolite with an electric blasting cap or Primacord detonating fuse. The explosive's high strength and efficient loading characteristics are expected to make it especially suited to hard breaking conditions in open pit mines.

Ref: Anon, C&EN, Nov 17, 1958, p 43

Explosive Capsule. An expl charge is made by loading the initiating expl into a small cap, which it partially fills, and then pressing the main expl charge onto this in the same mold. The cap, which then contains all of the initiating expl and part of the main charge, serves to hold the two together.

Ref: Poudreries réunies de Belgique SA, BelgP 528984 (1954) & CA 52, 5825 (1958)

Explosive Cartridge. A definition found in our notes says that such a cartridge contains a regular expl charge and, in a separate casing, an admixture of substances having high burning temperatures, such as Al, Mg, ferrosilicon or red P. No example of such cartridges is known to us. On the other hand, Yust, in the paper published in "American Rifleman", (See Ref), described under the title "Rifle Caliber Explosive Cartridges" the items which should be called "Rifle Cartridges with Explosive Bullets".

The following items are included in Yust's paper:
1) Argentine 7.65mm, Type R, HE cartridge manufd in Austria before WWI by Hirtenberg Patronenfabrik (See Fig 1 of Ref)
2) Austrian cartridges, Model 1910 and Model 1914, known as Einschusspatronen, were manufd at the government Arsenal at Wellersdorf. The expl in the 1910 Model consisted of KClO₃ & Sb₂S₃, while in the 1914 Model it was compressed BkPdr mixed with Al (Fig 2 of Ref)
3) Austrian cartridge of 1917, known as "airburst shrapnel" was included for use in machine guns (Fig 3 of Ref)
4) Austrian "antiballoon cartridges" of 1915 & 1916 were used in Mannlicher rifles (Fig 4 of Ref)
5) French "spot-light cartridges" in 8mm Lebel rifle existed in 2 patterns. Their expls placed in the cavity of bullet nose, was sensitive to detonation on impact (Figs 5 & 6 of Ref)
6) German 7.92 x 57mm WWI cartridges were of three types. Jackets of their bullets were of uncoated steel (Fig 7 of Ref)
7) German 7.92 x 57mm incendiary cartridge introduced shortly before WWII was known as B-Patrone. It was used as an observation cartridge for training purposes (Fig 8 of Ref)
8) German 7.92 x 57mm training cartridge which contained an explosive element, was known as "S.m.K. L'spur Ub.m.Z" (Spitzgeschoss mit Stahlkern und Leuchtspur Übung mit Zerstöter), which stands for "Pointed Bullet with Steelcore and Tracer, Practice, Self-Destroying", translated by Yust as "Practice Ball with Steel Core and Self-Destroying Tracer" (Fig 9 of Ref)
9) Italian 6.5mm expl cartridge of WWI could be recognized by an unusual shape of cupronickel-jacketed bullet (Fig 10 of Ref)
10) Japanese Navy 7.7mm rimmed expl cartridge of WWII was used in Naval machine guns, ground machine guns and was suitable for use in British .303 rifles and machine guns. The bullet had a cupronickel jacket. The front compartment inside the nose contained RDX or PETN; to the rear of this was a gilding-metal cup filled with Al & RDX or with Al & TNT. This was backed by a lead plug (Fig 11 of Ref)
11) Japanese Army 7.7mm, semi-rimmed expl round with flat-nosed, gilding-metal jacketed bullet is shown in Fig 12 of Ref
12) Japanese Army 7.92 x 57mm expl round which had a flat-nosed, gilding metal-jacketed bullet is shown in Fig 13 of Ref
13) Imperial Russian 7.62mm expl round for rifles and machine guns had a cupronickel jacketed bullet with flat nose. It cost the expl, detonator and firing pin (Fig 14 of Ref)
14) Soviet Russian 7.62mm incendiary cartridge had the gilding-metal cladded steel-
jacketed bullet. The front of the bullet contained thermite powder, followed by a lead sheath coating a detonator backed by a firing pin. A lead plug was in the base. Cartridge cases were either brass or copper-coated steel (Fig 15 of Ref)

15) United States .30 Gov’t M1906 H.E.

Pomerny expl cartridge, made by Winchester Co for the Government, is shown in Fig 16 of Ref. Its bullet had a pointed Cu tube inserted in the front end, which conta the expl charge

16) United States .30 Gov’t M1906 HE Spot-Light round is shown in Fig 17 of Ref

17) United States 11mm Machine Gun HE Spot-Light round is shown in Fig 18 of Ref

(See also under "Explosive Bullets" in this Vol)

Note: Later models of US expl bullets are described in this Vol, under "Explosive and Explosive Incendiary Ammunition."

Ref: Ch.H. Yust, Jr, "Rifle Caliber Explosive Cartridges", American Rifleman, January 1963, pp 22-4

**Explosive Catapults** are devices used for launching naval shipboard airplanes. Due to the lack of space aboard ships, it is impossible to have long enough runways to properly launch planes by ordinary means. Therefore, a catapult is used to impart sufficient initial velocity to the plane to launch it properly. Formerly, such catapults were operated by compressed air, but now expls are used. One method for launching planes is to fasten on the underside of the wings of a plane some rockets and then fire them at take-off time. This is now known as RATO (rocket-assisted take-off), but was formerly known as JATO (jet-assisted take-off) (Refs 1 & 3)

Catapults ejecting pilots and other personnel from rapidly travelling airplanes are ejected by cartridges contg propellants. They are known as CADs (cartridge-actuated devices) (Ref 2)

The general term for an auxiliary rocket engine specifically used for providing extra thrust to a heavily-loaded aircraft during take-off run and initial climb is ATO (assisted take-off) (Ref 1)

Refs: 1) Encycl PATR 2700, Vol 1 (1960), p A197-R [Assisted Take-off (Units)]


**Explosive Characteristics, Calculation of.**

Roth (Ref) described calculation of technically important expl characteristics by means of thermodynamic and hydrodynamic laws from known values of composition, heats of formation and densities

Ref: J. Roth, SS 35, 193-96, 220-21, 243-45 (1940) & CA 35, 1635 (1941)


Also an item, Explosive Cladding, is abstracted by G. Cohn Edit, in Expls&Pyros 2 (2), 1969 from Metalworking News via Technical Survey, Nov 30, 1969:

"Cladding the interiors of vats, containers for storage of corrosive substances, and even sheet metal tubs by explosive bonding techniques is becoming more popular in West Germany. In cases where high temperatures, with or without pressure, are involved, savings in structural costs up to 75% can be obtained. Today, almost all thickness combinations are possible with titanium on steel. These containers are also welded explosively."

**Explosive Combustion and Deflagration.**

See under Detonative (or Explosive) Combustion or Explosive Deflagration in Vol 4 of Encycl, p D731-L & R

**Explosive Compaction.** See under Explosive Fabrication of Metals
**Table Ex3**

<table>
<thead>
<tr>
<th>Composition:</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td>Min</td>
</tr>
<tr>
<td>RDX</td>
<td>98.5</td>
</tr>
<tr>
<td>Stearic Acid</td>
<td>1.0</td>
</tr>
<tr>
<td>Moisture</td>
<td>—</td>
</tr>
<tr>
<td>Insoluble Particles</td>
<td>Not more than 5 particles retained on No 60 Sieve and none on No 40</td>
</tr>
</tbody>
</table>

**Bulk Density**

- Min 0.95g/cc for Type I and 1.0 for Type II

**Granulation**

- Min 99.0% thru No 12 Sieve and max 2.4% thru No 200 Sieve

**Tests:**

4.4.1.1 Determination of Stearic Acid

Use the same procedure as item d on p D477-L of Vol 3. Add at the end: Repeat the above extraction, drying and weighing procedure with individual 20ml portions of chloroform until total loss in weight on subsequent extractions is less than 0.003g. Calculate the loss in weight of the crucible plus contents to % stearic acid on a moisture-free basis using the formula given on p D474-L of Encycl

4.4.1.1.1 Determination of Stearic Acid by Alternate Method which is described in Amendment 1, 24 Jan 1973 to MIL-E-14970A (MU)

- Add approx 5g of the prepd sample into a previously tared clean, dry, medium porosity crucible, contg a filter pad. Reweigh crucible and contents on an analytical balance and record the total wt to the nearest 0.0002g.

Place the crucible contg sample into a stainless steel pan located under a fume hood, and add 20ml of aliphatic naphtha to the crucible. Allow the solvent to remain in contact with sample at RT for about 5 minutes, while stirring the slurry and breaking-up any lumps. Remove the crucible from the pan and place it in the rubber ring located in the neck of a vacuum suction flask placed under
the hood. Suction filter the solvent and then repeat twice the above operations of adding 20ml naphtha, extracting for 5 minutes and filtering. Rinse the interior of the crucible with approx 20ml of naphtha from a wash bottle and aspirate the residue until the odor of naphtha is no longer detectable (approx 2 mins). Dry the crucible with residue in an oven at 90° to 105° for approx 30 mins, remove from oven, cool in a desiccator at RT and weigh to the nearest 0.0002g. Calculate % of stearic acid on a moisture free basis as follows:

\[
% \text{ Stearic Acid} = \frac{10(X-Y)}{W}
\]

where: 
X = Initial weight of crucible with sample 
Y = Final wt, after extraction and drying 
W = Weight of sample on a moisture free basis

4.4.1.2 Determination of RDX 
Subtract percent of Stearic Acid from 100 percent

4.4.2 Determination of Insoluble Matter
Use Method 106.1 of MIL-STD-650 with acetone as solvent: Weigh ca 50g of the expl to within 10mg, place in a 400-ml beaker and add 100ml of acetone. Heat on a steam bath until all lumps are broken and all soluble material is dissolved. Pour the mixture thru a small US Standard Sieve No 60 and wash the insol matter from the beaker onto the sieve with a stream of acetone. Wash the residue on the sieve with additional acetone to remove the undissolved soluble material. Dry the sieve and count and examine any particles remaining on the sieve. Brush any particles retained on No 60 sieve onto No 40 sieve. Note if the particles are grit as indicated by their lack of uniformity and a scratching noise when pressing and rubbing the material on a smooth glass slide with a smooth steel spatula. Report the number of particles on No 60 sieve and on No 40 sieve

4.4.3.1 Determination of Moisture 
Use Karl Fischer Method, described in MIL-STD-650 as Method 101.4, with methanol as the special solvent. A detailed description of the Karl Fischer Method is given under DYNAMITE in Vol 5 of Encycl, pp D1623 to D1627

4.4.3.2 Determination of Moisture by Alternate Method. This includes moisture and volatiles. For rapid determination use the "oven method" described in MIL-STD-650 as Method 101.5:

Spread a 5g sample, weighed to within 0.2mg, in a tared weighing dish (Al or glass), diam 60mm, depth 30mm, provided with a stopper. Heat in an oven at 100–105° for 1 hour, cover the dish and cool it to RT in a desiccator, containing an indicating desiccant. Reweigh the dish with sample and determine the loss of wt, A, subtracting dish + dry sample from dish + moist sample

\[
% \text{ Moisture} = \frac{100A}{W}, \text{ where } W = \text{weight of moist sample}
\]

Note: In case of non-agreement, the Karl Fischer Method shall be the standard

4.4.4. Determination of Granulation
Place a sample of 50±0.01g on a US Standard Sieve No 12 which is superimposed on top of a Sieve No 200, which is assembled with a bottom pan. Cover the upper sieve and shake the ensemble for 3 minutes by means of a mechanically operated (by remote control with adequate shielding) sieve shaker, which shall impart to the sieve a rotary, uniform motion and tapping action of 300±15 gyrations and 150±10 taps of the striker per minute. Weigh the portions (in grams) retained on or passed by the sieves and calculate the results to a percentage basis as described in Method 204.1 in MIL-STD-650:

\[
% \text{ Retained} = \left(\frac{A + B}{100}\right)W
\]

% Through = \left(\frac{W - (A + B)}{100/W}\right)

where: 
A = Weight retained on designated sieve 
B = Weight retained on sieves nested above designated sieve 
W = Weight of sample

4.4.5. Determination of Bulk Density
Use the apparatus consisting of a plywood box, 4x4x4 inches inside dimensions; padded inside top and bottom with ½-inch rubber foam of approx 0.029g/cc bulk density and provided in hinged top with a hole to fit a 250-ml graduated cylinder
Procedure: Weigh 200 g sample and pour it into 250 ml graduated cylinder. Insert the cylinder thru the above mentioned hole and close the box. Lift the cylinder until its bottom flange contacts the top of the box. Then drop the cylinder, again lift and drop it until 20 drops have been made, at the rate of one every 5 seconds. Read the volume of compacted powder in the cylinder

Calculate: Bulk Density = A/B

where: A = Weight of sample in grams
B = Volume of compacted sample in ml

Note: The following wet slurry method of coating has been found satisfactory. Add molten stearic acid at approx 70 °C to a hot water slurry of RDX at approx 70 °C and then, after thorough mixing, cool, filter and dry the coated product.

Explosive Compositions APX. See APX Explosive in Vol 1, p A475-L.

Explosive Compositions B, B-2, B-3, B-4, B Desensitized and Cyclotolts. See under Composition B Type Explosives and Cyclotolts in Vol 3 of Encycl, pp C479-R to C482-L. Also Specification MIL-C-401D, MIL-C-45113A(MU) and MIL-C-46652(MU).

Explosive Compositions, Brisant (of High Density). The following expl comps contg solid TNT and liquid nitric esters are described. Nitroglycerin 15-20, soluble Nitrocellulose 0-7.5, Kieselguhr 0-5, stabilizer 0-2.5, TNT 85-70%. The TNT is in the form of crushed flakes

Ref: J. Taylor and S.H. Davidson, BritP 578371 (1946) & CA 41, 1842 (1947)

Explosive Compositions C, C-2, C-3 and C-4 (Harristite). See under Compositions C Type Explosives in Vol 3, p C484-L to C488-L. Specification for C-3 is MIL-C-427A and for C-4 MIL-C-45010A(MU).

Explosive Compositions Cyclotolts. See Tables on pp C479 & C480 in Vol 3 under Composition B Type Explosives and Cyclotolts. AlsoSpecification MIL-C-13477B(MU)

Explosive Composition D-2. See Composition D-2 in Vol 3, p C488-R


Explosive Composition of Gordon and Littke. Heterogeneous expl comps are made by mixing NH₄NO₃ with an org fuel capable of forming a homogeneous melt below 170 °C, such as urea, hexamethylene tetramine or dicyandiamide, to form an O-balanced mixt. Mixt is quickly melted and then quickly cooled so that the crystals of ammonium nitrate have dimensions of <100μ and are embedded in a matrix of fuel

Ref: W.E. Gordon & A.D. Littke, BritP 1014071 (1965) & CA 64, 7962 (1966)


Explosive Compositions HBX-1 and HBX-2. See HBX-1 and HBX-3 Explosives in Vol 7 and in AMCP 706-177 (1971), pp 156 to 163

Explosive Compositions, HBX Type. See HBX Type Explosives in Vol 7 and Specification MIL-E-22267A, 31 May, 1963

Explosive Composition of Hradel. Solid expl mixts are produced by mixing 70-3% by wt NH₄NO₃ in soln with NH₃, H₂O, or their mixts with 27-30% of a light metal, such as Al or Mg. Components react exothermally during 0.5-9 hrs to form a solid expl. Preferably the metal is in a particular form. Detonation can be done by means of a shaped charge. Ref: J.R. Hradel, USP 3177102 (1965) & CA 63, 426 (1965)


Explosive Composition Minok-2 (and Minols 1 & 3). See Minol-2 in AMCP 706-177 (1971), pp 209 to 212, where also are given compass of Minols 1 & 3 but no properties. Specifications for Minol-2 is MIL-M-14745 (MU)

Explosive Compositions of Monsanto Co. A sensitive and powerful blasting expl is obtained by mixing 6 parts of a light fuel oil with 94 parts high density microprills having a bulk density of ≤100 lbs/ft³ and containing ≤94% NH₄NO₃, ≤5% of a hydratable salt, such as Mg(NO₃)₂, Al(NO₃)₃, Ca(NO₃)₂ and MgSO₄ to impart dimensional stability during storage; and ≤5% H₂O. Ref: Monsanto Co, BritP 988095 (1965) & CA 63, 1650 (1965)

Explosive Compositions MOX. See MOX-1, 2B, 3B, 4B and 6B in AMCP 706-177 (1971), pp 213 to 225

Explosive Compositions from Nitroated Toluene and Naphthalene. A soln of 30% C₁₂H₈ and 70% b.toluene is nitroated with 2.5 times its wt of an equal mix of sulfuric and nitric acids at 130° to give a product (I) mp 60° and contg 16.9%N. An expl is made by mixing

\[ \text{C}_3\text{H}_5(\text{ONO}_2)_5 \]

20, Nitrocellulose 0.8, wood powder 2, NH₄NO₃ 71.2 and 1 6.0% 


Explosive Composition NSX (Nitrostarch Demolition Explosive). See AMCP 706-177 (1971), pp 246 to 248

Explosive Compositions Octols. See Octol 70/30 and Octol 75/25 in AMCP 706-177 (1971), pp 247 to 258. Also Spec MIL-O-45445A

Explosive Compositions for Oil Well Gun Perforators. Expl charges consisting of the Pb Salt (I) of ethylenedinitramine or in combination with other heat stable propellants are suitable for deep well operations. This compd does not spontaneously explode under about 300° and it is a relatively powerful expl by itself. Low impact and friction sensitivity, moderate power or brisance, produces large vols of gas, high flash point. Ref: A.O. Franz, USP 2708623 (1955) & CA 49, 14326 (1955)

Explosive Composition PB-RDX. See PB-RDX in AMCP 706-177 (1971), pp 259 to 264

Explosive Composition PBXN-5. It consists of HMX 95 & Viton (vinylidene fluoride hexafluoropropylene copolymer) 5%, and has a rate of deton of 8760m/sec at density 1.82g/cc. Its military requirements are given in Specification MIL-E-81111A, "Explosive, Plastic-Bonded Molding Powder (Feb 1973)

Explosive Compositions Pentolites. See Pentolites 50/50 and 10/90 in AMCP 706-177 (1971), pp 272 to 275

Explosive Composition Picratol 52/48. See Picratol 52/48 in AMCP 706-177 (1971), pp 284 to 287
**Explosive Composition PIPE.** See PIPE in AMCP 706–177 (1971), pp 294 to 295

**Explosive Composition Plumbatol.** See Plumbatol in AMCP 706–177 (1971), pp 296 to 297

**Explosive Composition PLX (Liquid).** See PLX (Liquid) in AMCP 706–177 (1971), pp 298–301

**Explosive Compositions PTX-1 and PTX-2.** See PTX-1 and PTX-2 in AMCP 706–177 (1971), pp 306 to 311

**Explosive Composition PVA-4.** See PVA-4 in AMCP 706–177 (1971), pp 312 to 314

**Explosive Composition of Pyrochemie.** It consists of 60–95 parts by wt of "explosive acid" and 5–40 of a gelation agent. The acid is obtd by mixing 50–85 parts by wt of nitric acid, preferably 1.52 (contg ONOSO₃H and having N₂O₄ content 10 to 35%) and 15–50ps concd sulfuric acid contg oxidizable org or inorg substances (such as DNT, TNT, SiC, Ba or Amm sulfates). The gelation agent consists of finely divided voluminous SiO₂ having an apparent d preferably 0.040 kg/cm³ or of silicates of Al, Mg, Ca, Ba or Sr. The ratio ONOSO₃H:HSO₄ in acid is preferably >1.5:1

**Explosive Composition of Rinkenbach & Corroll: AN 79–84 & dry urea 21–16%; deton velocity 2900m/sec; equivalent in strength to 50% Dynamite

**Explosive Composition TRIP.** See R1PE in AMCP 706–177 (1971), pp 318 to 319

**Explosive Composition of Sato.** The expl consists of nitrourea 35–60, AN 20–40, NG 3–20 and urea 1–5%

**Explosive Composition of Scott.** Detonatable expl comps contg uncoated, prilled ammonium nitrate and uncoated, prilled calcium nitrate are discussed. Mixts contd 1–70% by wt of calcium nitrate and 4.5–8.46% by wt of carbonaceous fuel such as diesel oil. Combinations contg 60 wt% NH₄NO₃ with both 10–30 wt% of Ca(NO₃)₂ and 10–30 wt% NaNO₃ are also described
Ref: E.M. Scott Jr, USP 3180768 (1965) & CA 63, 426 (1965)

**Explosive Composition T-9.** See Composition T-9 in Vol 3 of Encycl, p C490-L

**Explosive Composition of Tetrytol.** See Tetrytol 80/20, 75/25, 70/30 and 65/35 in AMCP 706–177 (1971), pp 341 to 349

**Explosive Composition of Torpex.** See Torpex in AMCP 706–177 (1971), pp 359 to 363

**Explosive Composition of Trimonite.** See Trimonite in AMCP 706–177 (1971), pp 370 to 372

**Explosive Composition Trinonal 80/20.** See Trinonal 80/20 in AMCP 706–177 (1971), p 386 to 390

**Explosive Composition Veltex No 448.** See Veltex No 448 in AMCP 706–177 (1971), p 391 to 394
EXPLOSIVE D, AMMONIUM PICRATE OR DUNNITE. See 2,4,6-TRINITROPHENOL,
AMMONIUM SALt Under PHENOL AND DERIVATIVES

Explosive Conditioning. Mentioned, but not described, under Explosive Fabrication of Metals

Explosive Decomposition, Rate of. Using a special apparatus, which is a modification of that used by the US Ordnance Dept (See Fig Ex3), Henkin & McGill (Ref) determined expln temperature at various times of exposure. For expls which ignite or deflagrate on heating, 25mg samples were used and the results for several expls are listed in Table Ex 4

FIG Ex3. DIAGRAM OF APPARATUS
### Table Ex4

<table>
<thead>
<tr>
<th>Substance</th>
<th>Explosion Temp, °C</th>
<th>Exposure Time, Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetryl</td>
<td>346</td>
<td>0.325</td>
</tr>
<tr>
<td>(Trinitrophenyl-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>methyl nitramine)</td>
<td>314</td>
<td>0.742</td>
</tr>
<tr>
<td></td>
<td>285</td>
<td>1.45</td>
</tr>
<tr>
<td></td>
<td>269</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>264</td>
<td>No action</td>
</tr>
<tr>
<td>EDNA or</td>
<td>314</td>
<td>0.166</td>
</tr>
<tr>
<td>Haleite</td>
<td>251</td>
<td>0.45</td>
</tr>
<tr>
<td>(Ethylenedinitramine)</td>
<td>203</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>4.88</td>
</tr>
<tr>
<td></td>
<td>162</td>
<td>37.1</td>
</tr>
<tr>
<td></td>
<td>158</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>793.</td>
</tr>
<tr>
<td></td>
<td>142</td>
<td>No action</td>
</tr>
<tr>
<td>BkPdr (Black Powder)</td>
<td>359</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>320</td>
<td>34.1</td>
</tr>
<tr>
<td></td>
<td>315</td>
<td>No action</td>
</tr>
<tr>
<td>NC (13.4%N)</td>
<td>292</td>
<td>0.38</td>
</tr>
<tr>
<td>(Nitrocellulose)</td>
<td>264</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>234</td>
<td>5.80</td>
</tr>
<tr>
<td></td>
<td>198</td>
<td>41.4</td>
</tr>
<tr>
<td></td>
<td>174</td>
<td>120.</td>
</tr>
<tr>
<td></td>
<td>170</td>
<td>No action</td>
</tr>
<tr>
<td>NC (12.6%N)</td>
<td>350</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td>312</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>286</td>
<td>16.6</td>
</tr>
<tr>
<td></td>
<td>267</td>
<td>50.3</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td>No action</td>
</tr>
<tr>
<td>PA Picric Acid</td>
<td>350</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td>315</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>277</td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td>267</td>
<td>50.3</td>
</tr>
<tr>
<td></td>
<td>260</td>
<td>No action</td>
</tr>
</tbody>
</table>

### Table Ex5

<table>
<thead>
<tr>
<th>Substance</th>
<th>Explosion Temp, °C</th>
<th>Exposure Time, Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF</td>
<td>304</td>
<td>0.108</td>
</tr>
<tr>
<td>(Mercuric fulminate)</td>
<td>238</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>7.55</td>
</tr>
<tr>
<td></td>
<td>176</td>
<td>105.</td>
</tr>
<tr>
<td></td>
<td>170</td>
<td>No action</td>
</tr>
<tr>
<td>LA (Lead Azide)</td>
<td>360</td>
<td>0.560</td>
</tr>
<tr>
<td></td>
<td>341</td>
<td>0.865</td>
</tr>
<tr>
<td></td>
<td>319</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>314</td>
<td>No action</td>
</tr>
<tr>
<td>DADNP (Diazodinitrophenol)</td>
<td>247</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>0.725</td>
</tr>
<tr>
<td></td>
<td>177</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>168</td>
<td>16.</td>
</tr>
<tr>
<td>LSt (Lead Styphnate)</td>
<td>328</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>301</td>
<td>4.47</td>
</tr>
<tr>
<td></td>
<td>280</td>
<td>41.3</td>
</tr>
<tr>
<td></td>
<td>275</td>
<td>No action</td>
</tr>
<tr>
<td>NG (Nitroglycerin)</td>
<td>261</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>230</td>
<td>0.675</td>
</tr>
<tr>
<td></td>
<td>211</td>
<td>3.75</td>
</tr>
<tr>
<td></td>
<td>205</td>
<td>No action</td>
</tr>
<tr>
<td>EtTeN (Ethyrtitol)</td>
<td>275</td>
<td>0.108</td>
</tr>
<tr>
<td>(Tetranitrate)</td>
<td>239</td>
<td>0.475</td>
</tr>
<tr>
<td></td>
<td>205</td>
<td>4.95</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>No action</td>
</tr>
</tbody>
</table>

From the values of Tables Ex4 and Ex5 were estimated lowest expt temps, expt temps at exposure time of one second and the activation energy $E$ in kcal, using the formula:

$$ \log t = \frac{E}{RT} + \text{constant} $$

Results are listed in Table Ex6.

For expls which detonate on heating, 3mg samples were used and results are shown in Table Ex5.
## Table Ex6

<table>
<thead>
<tr>
<th>Substance</th>
<th>Expln Temp, °C</th>
<th>Energy, E for Lowest Temp</th>
<th>Energy, E for Highest Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lowest After 1 sec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetryl</td>
<td>265</td>
<td>300</td>
<td>27.4</td>
</tr>
<tr>
<td>EDNA</td>
<td>150</td>
<td>&gt; 350</td>
<td>80</td>
</tr>
<tr>
<td>BkPdr</td>
<td>175</td>
<td>270</td>
<td>67.0</td>
</tr>
<tr>
<td>NC(12.6%N)</td>
<td>265</td>
<td>360</td>
<td>20.6</td>
</tr>
<tr>
<td>PA</td>
<td>175</td>
<td>240</td>
<td>58.0</td>
</tr>
<tr>
<td>MF</td>
<td>315</td>
<td>340</td>
<td>21.1</td>
</tr>
<tr>
<td>LA</td>
<td>165</td>
<td>195</td>
<td>48.0</td>
</tr>
<tr>
<td>DADNP</td>
<td>280</td>
<td>320</td>
<td>58.8</td>
</tr>
<tr>
<td>LSt</td>
<td>210</td>
<td>220</td>
<td>22.6</td>
</tr>
<tr>
<td>NG</td>
<td>205</td>
<td>220</td>
<td>22.8</td>
</tr>
<tr>
<td>ErTeN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ref: H. Henkin & R. McGill, IEC 44, 1391–95 (1952) (9 refs)

Note: T. Urbanski & (?). Rychter, CR 208, 900 (1939) found for eleven expls tested by them that logarithmic relationship between the time lag prior to expln and the reciprocal of absolute temperature gives a straight line. Graphs for NC’s, MF, ErTeN and EDNA did not give straight lines.

### Explosive Deflagration.

See under Detonative (and Explosive) Combustion or Explosive Deflagration in Vol 4, p D731-L to D732-L.

### Explosive or Detonating Compositions of Mediavilla.

Hexamethylenetetramine (52g) is added to 184ml 100-vol H₂O₂. After agitation at 35° the mixt is cooled to 22° and treated with 50ml 39°Be HCl. White microscopic crystals are filtered and washed at 27°.

Ref: J. Mediavilla, SpanP 203467 (1952) & CA 48, 14210 (1954)

### Explosive Devices, Register of US Manufacturers.

See Expls&Pymts 5(4), 1972 (Table covering 2½ pages) and Ibid, 5(5), 1972 (Table covering ½ page)

### Explosive Diode (One-Way Detonation and Transfer Device).

A unitized device, called an "explosive diode", (US Patent Office Serial No 693358) is seen as a simple improvement over the multi-component, mechanical assemblies normally used for one-way explosive-energy transfer. Typical one-way transfer devices rely upon mechanical functions and percussion primers. Another "assembled components" design used in the industry relies on the precise placement of boosters to assure that a predetermined schmpnel dispersion allows functioning in only one direction. Both have drawbacks that limit their usefulness in the aerospace industry.

The explosive diode (See Fig Ex4) consists of a housing into which two cavities are provided to contain a donor charge and an acceptor charge. The position of the donor and acceptor charges within the housing are such that the donor will initiate the acceptor with a shockwave transfer thru the housing. Conversely, the shock generated by the acceptor charge, if detonated first, is dissipated by the geometrical configuration of the cavity in which the explosive is contained, so that any stimulus transmitted to the donor charge is insufficient to effect its initiation.

Explosive shocks in an essentially homogeneous medium travel in a well-defined and predictable path either until they dissipate.
their energy (as a function of the impedance of the medium through which they are traveling), or until they encounter and interface with a medium of a different shock impedance characteristic. Also, when a shock encounters such an interface, it will react in accordance with precise laws of hydrodynamics. The nature of the reaction is generally governed by: (1) the impedance of the associated medium, (2) the geometry or contour of the interface juncture, and (3) other factors associated with the characteristics of the advancing shock front. Thus when the diode's donor is detonated, a shock front is induced into the housing in a direction normal to the flat-bottomed surface of the donor cavity; i.e. toward the acceptor. Upon encountering the angled surface of the cone-shaped acceptor hole, the shock front is transferred in a direction normal to the free surface encountered. The advancing front will essentially converge at a point on the longitudinal axis of explosive material. The result of this converging shock front is an extreme concentration of energy that is sufficient to initiate an explosive having either minimal sensitivity, or a sensitivity such that it might not be initiated by a plane shockwave. This process of shock amplification (or augmentation) permits us to reduce the quantity of explosive in the donor charge or separate the donor and acceptor charges by a greater and less easily ruptured barrier. Either measure aids in precluding reverse detonation; i.e. detonation of the donor by the acceptor.

Geometry is the chief obstacle to reverse detonation. When the advancing shock front encounters the cone at the base of the cavity in which the acceptor charge is placed, the wave is transmitted normal to the surface of that juncture, and spatially dissipated away from the donor charge. It is therefore possible to place equivalent charges in proximity, while maintaining reliable go/no-go performance.

The new explosive diode incorporates high reliability, minimum weight, no moving parts, capable of functioning in extreme environments, flexibility in design applica-

tions, and good economy.

*Ref*:
1) G.W. Weaver, *Explosive Technology*, PO Box KK, Fairfield, Calif. 95533
2) G. Cohn, Ed., *Explos&Pyros* 1(5), 1968

**Explosive Disintegration, Explosive Fracturing or Explosive Shattering**. (See also Explosive Unit Operations)

It has been known for many years that certain materials, particularly those of a fibrous nature, can be disintegrated by first saturating them with a gas or vapor at high pressure and then releasing that pressure as rapidly as possible. One of the first to apply this method to practical use was Bancroft (Ref 1). He heated water-soaked crude mica in a pressure-tight cylinder to some desired pressure and then suddenly released it. The expl effect split the thick pieces of mica into thin leaves, suitable for preparing laminated insulation. In 1926, Mason (Ref 2) patented a process for exploding wood chips to prepare a product suitable for direct refining to paper or fiber board. Steam pressures up to 400-600 psi were used. Later patents of the same inventor, listed in Ref 6, improved the method. Pressures as high as 1000 psi were used.

Dean and Gross (Refs 3 and 4) carried out extensive investigations on the size reduction of ores by various intermittent expl processes. Godwin (Ref 5) found that coal can be partly pulverized by saturating it with superheated steam under high pressure (1500 psi) and then releasing the pressure by opening a valve.

The Germans learned before WWII that if a material with a high internal moisture content is suddenly introduced into a stream of hot gas, a considerable disintegration takes place, caused by generation of steam inside the pores of the material. The Winterscholl-Schmidfeld process was a commercial application of this property.

*Ref*:
1) G.J. Bancroft, USP 1383370 (1921) (Splitting of crude mica by explosive forces)
2) W.H. Mason, USP 1578609 (1926) (Splitting wood by expln)
4) Ibid, "Crushing and Grinding", USBurMines
Explosive Driven Anchor. Accdg to Goodyear Aerospace Corp of Akron, Ohio, 44315, expl driven anchors were to be used to moor a very large balloon. Periodically the balloon must be moved and anchored with extreme rapidity with emphasis on anchoring the balloon securely in the shortest time possible. The expl driven anchor concept appears to be the most expeditious means for this task. The anchor must be capable of being driven into all types of soil and sustain a 1000 pound pull for a period of 48 hours. Fragmentation cannot be tolerated upon actuation of the expl charge.

Ref: G.Cohn, Edit, Expls & Pyrotecs 1(11), 1968

Explosive Driver. It is a device for efficiently converting the chemical energy of a HE to the kinetic and internal energy of a gas. The basic element is a rhin-walled metal tube, filled with a desired gas, surrounded by a concentric cylinder with HE, such as NM (Nitromethane). A detonation, initiated at one end of HE, collapses the metal tube as the deton wave front propagates thru the cylinder in much the same manner as toothpaste is squeezed from a tube. The progressive collapse of the tube can be thought of as a piston moving at the deton velocity of the HE. Since ordinary HE’s have deton velocities that range from 5 to 9 thousand meters per second, these are the gas velocities that can be achieved. Temperatures resulting from the shock wave can reach 5 to 15 thousand degrees Kelvin, while pressures of 8 to 300 thousand psi are possible. The conversion of chem energy of an HE to the kinetic and inter-

Explosive of DuPont Co. Coal Mining expl cond: AN75-90, PETN 7-20, the rest being Na nitrate. Carbonaceous material 3-10% could be added.

Ref: E.I.du Pont de Nemours & Co (Inc), Ger P 1130342

Explosive “E”. See Explosif E (Swiss) in this vol

Explosive Effect of an Explosive. Accdg to Naom, NG (1928), pp 154 & 156, tests like Trauzl or Crusher give a practical measure of the “explosive effect of an explosive” or the work done in actual practice by an expl.

Explosive Emulsion. A blasting agent is prepd by emulsifying up to 70% of a liq or meltble hydrocarbon with a liq or meltble expl using up to 5% emulsifier. An example is: NG 50cc, liq paraffin 50cc, oleic acid 1cc & sol Gon-cotton 1.2g. The common inorganic oxygen carriers, such as AN, may be also incorpora-

ted to give higher brisance.
Explosive Envelopes & Packages. An active campaign has been conducted by terrorist elements since Dec 1971 to deliver envelope and/or package bombs to selected personnel who are in disagreement with terrorist activities. Initially, packages were mailed from Israel and in July & August 1972, letter bombs were intercepted that had been mailed from Beirut, Lebanon. More recently envelope bombs have been received in several nations, including USA, Canada, England & Germany which were mailed in Amsterdam, Holland and Penang, Malaysia.

The basic descriptions of the bombs identified to date are:

a) Envelope bombs varying in size from 3 x 6 inches to 8 x 11 inches. The thickness has varied from 1/8 to 5/16 inches with a weight of approximately 1.7 ounces. Both standard airmail and plain envelopes in a variety of colors have been found. Addresses have been either handwritten or typed on a 1 3/4 inch x 3 1/4 inch white label with red trim or directly on the envelope. It is important to remember that with clandestine devices of this type, the envelope sizes, shapes, colors and postmarks may vary extensively.

b) Package bombs recently received have been about 5 x 5 1/2 inches and have weighed approximately 1 pound. Each was packaged as either a gift desk calendar, book or box of candy. The outside package cover was an envelope and most packages were addressed in green ink. These items also could be received in a great variety of sizes, shapes and colors.

It should be stressed that all previously described items may be mechanically or electrically initiated to explode when the envelopes or packages are opened, resulting in death or injury to personnel. Should envelopes or packages resembling above descriptions be encountered, avoid handling the items insofar as possible, evacuate personnel from the immediate area, and notify the appropriate Explosive Ordnance Disposal personnel.

Explosive Excavation, Instant. The Corps of Engineers is in the process of developing a construction technique called "explosive excavation" which promises to save money, time, and the environment. Rows of 1 to 10 ton explosive charges are buried in a pattern to both break up the material and move it out of the excavation (See Fig Ex5). Controlled blasting techniques minimize fracturing beyond the excavation boundary. Illustration shows arrangement for a 500-foot long railroad cut at Trinidad, Colorado. In several demonstrations, cost was less than
conventional earth moving or dredging operations. In underwater detonations, fish kill is said to be no greater than when using conventional methods
2) G. Cohn, Edit, Expls&Pyrots 6(4), 1973

Explosive and Incendiary Ammunition. Acddg to reprint available in PicArsnLibrary, Vol 2 of "Small Arms and Small Arms Ammunition" obtained from the Office of Chief of Ordnance, Jan 1946, reported:
During the period 1920–1941 extended research was conducted by the Ordnance Department to develop small arms explosive bullets. No round was developed which functioned with complete satisfaction in a hot machine gun barrel, the decomposition temperature of all known military explosives is lower than the temperature encountered in the combat firing of small arms machine guns. The nearest approach to a satisfactory explosive cartridge was the T1 Pomeroy type

"Explosive bullets were abandoned during WWII due to the limited quantity of explosive which could be carried in a small arms projectile, as well as the effectiveness of incendiary ammunition which resulted in complete aircraft or vehicle destruction
Throughout the war the popular conception of the laymen was that the army needed an explosive cartridge. Numerous types were submitted for test, none was adopted"

The first expl cartridge was developed by the OrdnDept before WWII. It was Cartridge, Spotlight, Caliber .50, TIE1, assembled with a bullet contg a supersensitive nose fuze which included a floating firing pin, centrifugally operated safety segments, a primer and an expl charge of 22 grains of PETN. The cartridge was found to be unsatisfactory for loading in the caliber .50 machine gun because of the sensitivity of the fuze. The TIE1 expl bullet was therefore dropped by the Ordnance Committee in 1937. The Committee recommended, however, that the development of cal .50 HE ammunition be continued to provide a bullet effective on impact with .125-inch dural sheet

In 1939 the Ordn Dept became interested in the Pomeroy design which used Dynamite as an expl chge. Upon firing, the rotation of the gun barrel resulted in the centrifuging of the NG from the inert kieselguhr base, thus arming the bullet in flight. The Winchester Repeating Arms Co manufd limited quantities of caliber .30 and cal .50 cartridges based upon Pomeroy design

In Aberdeen Proving Ground Tests in the spring of 1940, it was found that the cal .50 cartridge designated as Cartridge, Explosive, Caliber .50, T1, was satisfactory in many respects, except that it could expl in a very hot machine gun barrel. As a result of these tests, the cal .50 cartridge was standardized and 15000 rounds were manufd during 1940 (Its bullet is shown in Fig Ex6). During the same period 3000 rounds of Cartridge, Explosive, Caliber .30, T1 were manufd (Its bullet is in Fig Ex7)

Meanwhile, development work by the Army Air Forces on incendiary ammunition resulted in decreased emphasis being placed upon the explosive cartridge project. As a result of tests covering a period of nearly two years, recommendation was made that incendiary ammunition be used instead of explosive for all loadings where the targets are aircraft either in flight or on the ground. The test program upon which the foregoing findings were reached included both cal .30 and cal .50 Pomeroy type ammunition. Compositions of incendiary mixts of WWII are given in Vol 2, pp B329 and B330

In the spring of 1943, F.L. Shovic, an employee of the Army Air Forces at Great Falls, Montana, reported that by removing the standard incendiary mixture from the cal .50 M1 bullet and replacing it with a mixture composed of 8 parts K chlorate, 4 p of sulfur, 6 p Mg, 3 p Sb sulfide and 1 p hydrogen-reduced iron powder, the bullet had greater destructive power in firing against aircraft. The tests conducted at Frankford Arsenal showed that the Slovic bullet was not as effective as Bullet, Incendiary, Caliber
FIG Ex6
BULLET, EXPLOSIVE,
CALIBER .50, T1
FIG Ex7
BULLET, EXPLOSIVE
CALIBER .30, T1
BULLET, INCENDIARY, EXPLOSIVE, .30, FA II

ASSEMBLED BULLET
WT. 330 GRS. Approx.

JACKET
Gilding Metal, Clad Steel
Type I, Class 2, FXS-580
WT. 213 GRS.

SLUG
Lead—Antimony
WT. 360 GRS.

NOTE:
* Light Blue No. 118
Color Card Spec. No.3-1
** Yellow No. 120
Color Card Spec. No.3-1
SLUG
Lead–Antimony
Wt 137-4 Grs
For Dimensions See
Drawing A185029

JACKET
Gilding Metal
Wt 235-5 Grs
For Dimensions See
Drawing B174992

PIN, TUBULAR DOWEL (LARGE)
FXS 535 – Type I
Steel–WDX1112 (S.R.Q. Macro Etch) Class A
Powdered Iron – Class B – Hardened
Steel Tubing – Class C
Finish
Wt 197 Grs Approx
For Other Dimensions See Drawing A299569

ASSEMBLED BULLET
Wt 602 Grs Approx

FIG Ex9
BULLET, INCENDIARY, EXPLOSIVE,
CALIBER .50, FA T2
.50, M1. It was also shown that Slovic mixture is very sensitive and this was confirmed by extensive tests conducted at Picatinny Arsenal. No further consideration was given to the Slovic bullet.

In an effort to develop a more efficient incendiary bullet, a project was initiated before 1944 at Frankford Arsenal to develop bullets combining the properties of HE (high expl) and I (incendiary) type bullets. The following types, belonging to Cartridge, High-Explosive-Incendiary, Caliber .50, T34 were submitted in 1944 to tests:

**Bullet, Incendiary, Explosive, Caliber .50, FA T1**, shown in Fig Ex8 consisted of gilding metal clad steel jacket, contg 10 grains of compressed incendiary mixture IM**.11, de-tonator M17, 37 grams of Tetryl added successively and 360 grains Pb-Sb slug; its base was flat; total wt of bullet 628 grains

**Bullet, Incendiary, Explosive, Caliber .50, FA T2**, shown in Fig Ex9, was manufd by inserting into gilding metal jacket a pin tabular dowel (large), contg .242-inch hole, 10 grains of incendiary (compressed) IM-11, detonator M17, 18 grains of Tetryl added successively and Pb-Sb slug weighing 137 grains; its base was boat-tail; total wt of bullet 600 grains.

Both types of bullets were assembled into complete rounds with 227 grains of IMR-4903, AL-2674, as a propellant.

Note 1: Incendiary IM-11 consisted of 50/50 Mg-Al Alloy 50 & Barium Nitrate 50%

Note 2: Propellant IMR-4903, AL-2674 is presumed to have consisted of NC (13.5-13.25% N) 98.3, K2SO4, 1 & DPhA 0.7%

Following were ballistics for above rounds:

<table>
<thead>
<tr>
<th>Round</th>
<th>Velocity at 780 feet</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA T1</td>
<td>2909 fps</td>
<td>49220 psi</td>
</tr>
<tr>
<td>FA T2</td>
<td>2918 fps</td>
<td>49060 psi</td>
</tr>
</tbody>
</table>

Preliminary firings indicated that the bullets did not withstand "cook-off" tests. More detailed tests conducted at the Ordnance Research and Development Center gave the following results:

When a round contg FA T2 bullet was placed in a hot machine gun barrel after 100-round burst, no premature ignition or expln of the bullet took place.

When an identical round was placed in the barrel after 125-round burst, premature expln of the bullet occurred with bulging of the barrel.

The bullet placed after 150-round burst detonated with force splitting the barrel and bulging the chamber.

Similar results were obtd with rounds contg FA T1 bullet.

The above "cook-off" tests proved that both types of ammunition are not suitable for use in machine guns.

Similar unsatisfactory "cook-off" premature were obtd with Caliber .50 Explosive Bullet developed by the Hunter Manufacturing Co and submitted in 1943 to tests at Aberdeen Proving Ground. The bullet had a firing pin, a LA detonator, an arming wire in the nose, and an expl charge of 15 grains of Tetryl.

**Explosive Fabrication of Metals.** This term includes explosive forming, -forging, -sizing -welding, -compaction, and -conditioning. Other processes of minor interest are embossing, shearing, flanging, jogging, threading, punching, pressing and extraction.

Accdg to V. Philipchuk (Ref 7), in conventional process of metal fabrication the pressure is usually supplied by a hydraulic press, while in expl fabrication the pressure is supplied by expln of a calculated charge of expl. The difference between the two techniques is the pressure-time work curves, which, essentially, show a major difference in stress-strain applications.

Fig Ex10 shows the difference in the stress rates in conventional and expl forming. In expl forming the metal moves rapidly thru its elastic range and into its plastic range, producing permanent set of shape within microseconds. A complete understanding of the action taking place in the metal under high stress-strain rates is not known and here one can only theorize. Practically all metal-fabricating processes require forces of vary-
Vol 4 of Encycl, pp D442-R to D457-R, under DETONATION, MUNROE-NEUMANN EFFECT

Prior to 1900, German, American and British engineers were awarded patents for expl forming methods, but the technique lay dormant until about 1954 when interest in it revived. The advent of the missile age with its large and complex parts, high strength materials, close tolerances, and relatively low production volumes appears to have provided the greatest impetus to the method, although the Moore Co of Marceline, Missouri, was one of the first to recognize the benefits of this method for commercial production operations.

Very important work, beginning prior to 1958, was done at the National Northern Plant, West Hanover, Mass under the direction of Phillipchuk (Refs 4 & 7). There were manuf small and large parts for aeroplanes and jet-motors. For example, the jet-motor housing shown in Fig Ex11 was explosively formed.

Accdg to Ref 10, the use of expls to do construction work is not new. About 1888 Amer scientist C.E. Munroe (1849-1938) used expl charges to engrave names and designs on iron plates by procedure in use at the present time. As a result of his work and of the work of German scientist E. Neumann, the process known as the "shaped charge effect" was developed. It is described in
A simple arrangement, shown in Fig Ex13, was published in the Fortune Magazine for Sept 1961 (Ref 9). The device consists of a liquid contg tank, female die, vacuum pump and an expl with some means of detonation. The liquid (such as water) served as a medium for the transferral of the shock waves (which supply the major portion of the energy) and gas pressure generated by the detonation of the expl. A vacuum pump is required to evacuate the die cavity to reduce forming resistance and to eliminate the burning of the die side of the material and the die. This burning is a result of the excessive temps (as high as 10000°F) generated by the compression of the gas entrapped in the die cavity. It was necessary in some cases to draw a vacuum of 29.5 inches Hg in order to prevent the autoignition of the die lubricant which occurred at higher absolute pressures. This autoignition can create springback and dents in the part being formed.

The transfer media can be, besides water: hydraulic oils, molten salts, molten alloys, rubber, glass, sand, air or inert gas. The expl may be PETN, RDX, TNT, NG, 30% Ammonia Gelatin or NGu (Nitroguanidine) and may be used in the form of a powder, sheets, liquid, cords, pellets or cylinders. In general, any expl that is homogeneous and can be handled safely may be used (Ref 10).

the metal part (Fig Ex12). A female die having the desired finished contour is behind the metal part. Depending upon the starting and final shapes, the necessity for a vacuum btw the die and the part is determined. The expl charge is detonated, transmits the pressure pulse to the metal part, and forces it into the shape of the female die.
The metals and alloys that have been under test at National Northem were before the publication of Ref 7 the following:
plain carbon steels, alloy steels, stainless steels; Ni, Al, Mg, Ti & Cu alloys; Zircalloy-2; Ta, U, Ber, Niobium (Columbium), W (Wolfram or Tungsten) and Mo. They have been in either one or more of the following starting forms: sheet, plate, cylinders, cones, powders and pellets.
Weights of parts formed have ranged from a few grams to over 2 tons.
The methods for forging, welding, compaction and conditioning require preparation of the metal and die surfaces prior to the operation. Each of these operations requires higher pressure forces than those needed for exp forming of sheet material. Most of the operations are such that the fabricating process can be set indoors. Extremely large parts, or those requiring great quantities of exps, are processed out-of-doors to prevent residual and reflected shock or blast fronts from damaging the buildings (Ref 7, p 3)

**Explosively forged** materials manufd at National Northem exhibited physical properties above minimum conventional requirements and are considered of good quality (Ref 7, p 5)

**Explosively compacted** materials, such as Ti and steel, have produced small pellets, ca 1 x 1 inch, having densities of over 95% of theoretical without a sintered operation. It is there that a new branch of powder metallurgy, i.e. high pressure in place of high temp, and a combination of both, is under way (Ref 7, p 5)

**Explosive conditioning** mentioned in Ref 7 is not described.

**Explosive extrusion** has been investigated by the Air Materiel Command of the US Air Force but it is not described in Ref 7. Explosive welding, mentioned in Ref 7, pp 3 & 5 is described as a separate item.

**Explosive forming** is used for manuf parts which cannot be made by other methods (See also Explosive Metallurgy; Explosive Metalworking, High-Velocity; Explosive Press; and Explosive Welding)

**Refs for Explosive Fabrication of Metals:**
1) Anon, Steel 143(8), 82-6(1958) (Pressing and drilling holes by using shaped charges)
2) Anon, Materials and Design Engineering 47(1), 168-72(1958) (Explosive forming, shaping and punching of metals)
3) Anon, Product Engineering 30, April 20, 1958, p 26 (Explosive forming)
5) Anon, Steel 144(3), p 62(1959) (Why explosive forming works)
6) Anon, Machinist 103(12), 127-38(1959)
7) H.T. Hall, "Ultrahigh Pressures", Scientific American, November 1959
10) Anon, Fortune Magazine, September 1961 (Explosive Forming)
11) Anon, "Review of Explosive (Chemical) Forming", USAry Production Equipment Agency, Manufacturing Technology Division, Roch Island Arsenal, Illinois, April 1965 (164 refs)
13) J. Pearson, NAVORD Rept 7033(NOTS TP2421), China Lake, Calif 1966 (Expl working of metals)
14) G. Cohn, Explo & Pyrots 4(7), 1971 (Explosive forming for manuf metal plate dentures)

**Addl Refs on Explosive Fabrication of Metals.**
A) L.I. Islamoff, "Metal-Forming Techniques", NASA, SP-5017 (May 1965)

**Explosive, Flexible of Kegler.** It may be prepd by mixing an expl with an elastomer (depolymerized natural or synthetic rubber) and a vulcanizing agent. Vulcanization is carried out simultaneously with formation of the product. For example, 500g dry PETN of particle size <100μ was mixed with 200g liquid depolymerized natural rubber(such as
Lorival-R), having viscosity of about 5000 cp, to give viscous mass which was subjecting to flating and 200g of PETN added. When the mixture was homogeneous, 5g Colloidal S, 5g ZnO, 2g Vulcacit P, and 3g antioxidant 4010 were added, and the resulting mass was converted to plates on a 2 cylinder colander.

Ref: W.Kegler to Institute Franco-Allemand de Recherches de Saint-Louis, FrP 1308664 (1965); Swiss Appl June 19, 1963 & CA 64 3276-77 (1966)

Explosive Force. Its definition is given in Vol 4 of Encycl, pp D391-R & D392-1, under Detonation (and Explosion) Impetus and Available Energy. Haid & Koenen (Ref) described a modification of Kast's Apparatus, known as Briasance Meter of Kast, shown on p C493 of Vol 3, which they used for measuring expl force. Comparative values otd by crushing Cu cylinders were TNT 10.1, DNBz 6.2, PA 12.2, Tetryl, 14.0, PETN 17.0 & MF 18.6

Ref: A.Haid & H.Koenen, SS 28, 369-72 (1933) & 29, 11-14 & 13-17 (1934)& CA 28, 2907 (1934)

Explosive Forging. Mentioned but not described under Explosive Fabrication of Metals

Explosive Forming. See under Explosive Fabrication of metals

Explosive Fracturing or Shattering. See Explosive Disintegration

Explosive Fracturing for Well Stimulation, Accdg to Refs the USButMines in cooperation with Sun Oil Co investigated the application of expl fracturing for stimulating natural gas recovery. Two tests conducted in the shallow Buzzard Sand formation in Osage County, Oklahoma, demonstrated that desensitized NG can be safely loaded, displaced and detonated in hydraulically induced fractures both in open-hole intervals and thru casing perforations


Explosive Gas Gun. The gun consists of a steel pressure tube containing helium gas and a projectile. The tube is surrounded by a high expl (Nitromethane). The gun is operated by detonating the HE. The detonation front propagates along the steel tube causing it to collapse. The collapsing wall of the tube acts like a piston traveling at the detonation velocity of the HE. This motion sends a shock wave into the helium gas which accelerates the gas to the detonation velocity of the HE. Projectiles weighing up to 100 grams can be ejected at a velocity of approx 18000 ft/sec. The proposed use of the gun is to simulate condition of re-entry of space capsules. The tentative parameters of such a gun are total length 15 ft, barrel length 4 ft, projectile dia 2.5 inches, projectile length 1.5 inches, projectile wt 101 gms, helium gas 216 lbs, Nitromethane 143 lbs


Explosive Gases. See Vol 4 of Encycl, Tables on pp D352, D356 & D360

H.T.Titman & A.Wyman discussed in Rev Ind Minérale 36, 50-61 (1955) & CA 49, 9729(1955) the ignition of gaseous mixtures by friction

Explosive Generators are devices for converting energy of explosions into magnetic field energy. They are systems with variable inductance in which the moving conductors, accelerated by an expl, work counter to the ponderomotive force of the magnetic field and thus cause an increase in the energy of the field. Two types of generators were prepd and tested in Russia: 1) a two-bar generator and 2) a coaxial generator. Their construction and results of tests are described in Ref. In
one successful experiment, the efficiency of conversion was 12-14%  

**Explosive High-Velocity Metalworking.** See Explosive Metalworking, High-Velocity

**Explosive of Holt and Hispano Suiza SA.** It was prepared by mixing gelatinized NC with 10-60% of HE (such as RDX, TNT, etc.) and oxidizing salts (such as nitrates, chlorates and perchlorates). The solids had grain sizes of 0.1-2.0 mm and were homogeneously distributed in NC jelly.  
Ref: E.von Holt & Hispano Suiza SA, Tanger, Ger P 1010887 (1957) & CA 54, 8087 (1960)

**Explosive Initiation Evaluation.** A model described by Evans is derived based on heat-transfer considerations. It indicates performance of an expl charge in contact with a thermal bridge. The result gives bridge temperature as a function of time, current, and the physical properties of the bridge and expl.  

**Explosive of Ioda.** An expl compo claimed to be as powerful as Tetryl or RDX, was prepared by thoroughly blending a pulverized mixture of AN and/or K(Na) nitrate with Al and a jelly consisting of NC, NG in volatile solvent (such as Methanol). After pressing to the desired density (1.4 to 1.6) and grain size, the solvent was allowed to evaporate.  

**Explosive Lead Salts, Formation of During Manufacture of TNT.** Supporting evidence on the formation of Pb salts is given based on studies on the mechanism of purification of TNT by Na_2SO_4 washing.  

**Explosive Linear Charges.** See under Explosive Streamers

**Explosively Actuated Tools.** Under this heading A.H. Oldham, Army Ordn 18, 361-6, (1938), reviewed some of the patents relating to the operation of tools and other mechanical devices actuated by means of expls. Among these tools are cable cutters, cable killers, circuit breakers, engine starters, joint making apparatus, log-splitting tools, pile drivers, pin driving apparatus, rail bonds, riveters, explosively operated hammers, ship salvage and well-casing tools.

**Explosive Limits and Flash Point Derivation of Empirical Equations for the Lower Explosives.** A summation of oxygen demand for each of the atoms in the fuel molecule gives a value which, combined with the boiling point gives the flash point, and which combined with the reaction stoichiometry gives the lower expln limit. Some oxygen demand values are C + 4, H + 1, S + 4, O = 2.  
Ref: (3) Oehley, “Ableitung empirischer Gleichungen für die untere Explosionsgrenze und den Flammpunkt”, Explosivstoffe 1956, 93.

“**Explosive Metallurgy**” is the term coined by the authors of Ref to embrace the techniques, sciences and phenomena involved in the application of expls to the processing of metals. The term includes items described in this Vol, namely “Explosive Fabrication of Metals”, “Explosive Forging”, “Explosive Forming”, “Explosive Pressing” and “Explosive Welding” (See also Explosive Metalworking)  
Explosive Metalworking, High Velocity. Noland et al (Ref 1) included in a well-illustrated 79-page chapter on explosive metalworking the components of explosive processing systems, metalworking facilities, controls, tube forming, sheet metal and plate forming, dishes and domes, hardening and forging, welding and powder compaction. Shorter, but equally well done chapters describe electromagnetic, electrohydraulic and pneumatic-mechanical metalworking. Authors also give background on die design for sheet metal forming and forging, and on material behavior at high strain rates. Many advantages of the method are cited. As an example "Explosive sizing of cones or cylinders" is shown in Fig Ex 14 (See also Explosive Metallurgy, Explosive Fabrication of Metals, Explosive Forming and Explosive Welding).

![Diagram of Explosive Sizing of Cones or Cylinders]

**FIG Ex14**

**EXPLOSIVE SIZING OF CONES OR CYLINDERS**


Explosive Mixture, French. See Frantsuzskaya Smes' (Russian)

**Explosive Mixture, French and Spanish.** See Ref and under individual name of expl

*Ref.:* Société d'Explosifs et de Produits Chimiques, Spain P 236626 (1962) & Kemixon Reporter (Barcelona), Jan 1963, Item 11-17440

Explosive Mixture of Methanol-Water-Magnesium (or Aluminum). On the basis of theoretical calcs of heat of evolution, the author concludes that mixts of Mg or Al with water or alcs are potentially more powerful explos than the usual military materials, with MeOH-Mg giving max gas evolution. The experiments were conducted in bombs or lead enclosures with Tetryl detonators to set off the mixt of powd metal & liq. All mixts were shown to be powerful explos, with water-Mg being the most sensitive to shock, while water-Al & MeOH-Mg were less sensitive and reqd a booster detonator. Photographs of the exploded vessels & bombs are shown for this new type of expl comps

*Ref.:* A.A. Shidlovskii, ZhurPrikKhimi 19, 371-78 (1946) & CA 41,1105 (1947)

Explosive Mixtures. T. Urbański (Ref) reviews properties of numerous expl mixtures, described by previous investigators and also prepd by him and collaborators. The title of his paper is "Sur quelque régularités observées dans les propriétés de certain mélanges explosifs"

*Ref.:* T. Urbański, MAF 20, 237-63 (1946) (55 refs). The properties detd include ignition (or expln) temperature, impact sensitivity, Trauzl Test and detonation velocity.

Explosive Mixtures, Detonability of. A study of detonability of liquid binary and ternary mixts of NMe(Nitro methane), hydrazine and methanol showed that hydrazine strongly sensitizes NMe and NMe-methanol mixts to de-
tonation. However, the binary and tertiary mixtures were insensitive in the drop-weight impact tests. Theoretical calculations yielded reasonable estimates of the energy content of mixtures. Refs: 1) D.R. Forshey et al., Explosivstoffe 17(6), 125-29 (1969) 2) G. Cohn, Editor, Expls & Pyrods 3(2), 1970 (Abstract)


Explosive Mixtures of Gases, Flame Propagation in. A system of differential equations of flame propagation is set up and discussed. The energy equation reduces to the form of Abel's differential equation of the 2nd type. A simple numerical solution is developed. General theory developed is check by expts with exphm flame of O₃ and O, for which complete and reliable kinetic data are available. General theory is applied to mixths of Methane and Nitrogen air, helium air, and argon air. It was found to be applicable only when dissociation of the end products is negligible. Temp distribution in the flame zone is calculated on the well-founded basis of const. enthalpy. Ref: R. Sandri, Can J Chem 34, 313-23 (1956) & CA 50, 12481-2 (1956)

Explosive Mixtures of High Density. A method of prep'd, patented by Cook & Davis, involves subjecting two solid chem comps, at least one of which is a nitroxyd org cmpd (such as a mixture of TNT, AN and other compds), to a temperature at which at least a portion of one of the compds is in molten condition. To this molten mass is added a dispersing agent (such as a Na alkyl naphtalene sulfonate or other suitable org sulfonate or fatty acid soap) and then, after thorough blending, the mass is cooled and solidified. Several examples with details are given. Ref: M.A. Cook & C.O. Davis (To E.I. duPont de Nemours & Co), USP 2353147 (1944) & CA 38, 6098 (1944)

Explosive Mixtures of Koch. They are prep'd by coating a high-melting expl with a low-melting one. The latter is added to a strongly agitated suspension in water of the high-melting expl. Then the mixt is cooled until the low-melting expl solidifies. Ref: G. Hoch to Wasag-Chemie AG, Ger P1038470 (1958) & CA 54, 16832-33 (1954)


Explosive Mixtures of Streng and Kirschenbaum. High-explosive mixtures contg finely divided metals (such as Al) and an aqueous soln of an oxidizer (such as AN or a perchlorate). Thus 30 parts 60-Mesh dry NH₄NO₃ was dissolved in 28 parts water and resulting soln added with constant stirring to 42 parts of a mixture of equal parts granular 400-Mesh and flake 100-Mesh Al to give suspension with a rate of dem of 400-200 m/sec when initiated by a No. 6 cap. Dispersing, emulsifying, and wetting agents may be added. Ref: A.G Streng & A.D. Kirschenbaum, USP 2836484 (1958) & CA 52, 14172 (1958)

Explosive N (Methylite 20 & 25). Expl compns consisting of NG/dimethylphthalate/stabilizer (not specified). The NG used was a commercial grade contg ethylene glycol 25, Ethylene glycol Dinitrate 30 or Diglyceric Tetrinitrate 30% to depress its freezing point. Props of Explosive N are as follows: Methylite 20 is NG/dimethylphthalate/stabilizer 80/19.2/0.8%. Its fr p -30°, impact sens 49 (TNT=100 cm) & bullet sensitivity-not detonated by .50 cal bullet; initiated by ES cap & booster, and velocity of deton 7000-7300 m/sec at d 1.48 g/cc.

Methylite 25 is NG/dimethylphthalate/stabilizer 75/24.25/0.75%. Its fr p -30°, impact sens 56 (TNT=100 cm) & bullet sensitivity-not detonated by .50 cal bullet; initiated by ES cap & booster, and velocity of deton 7000-7300 m/sec at d 1.47 g/cc.
 Explosive or Blasting Oil. A laymen's term for oily expls NG, NGe, etc used in Dynamites and other Blasting expls

Explosive Operated Valve. A device to seal the sample containers of the Cane Sequenced Sampler used by the Oak Ridge National Laboratories to obtain gas samples of underground detonations of nuclear explsn, (Project Gnome). The valve design is based upon the use of aluminum tubing, 0.5 inch O.D. and 0.065 inch wall. The explosive load consists of 17½ inches of 30 gr/ft. PETN Primacord wound in five tight turns about the tubing. A detonator is attached. For confinement of the explosion, a shell of mild steel tubing with a neoprene liner is slipped over the expl charge. A seal is obtained that has all appearances of a weld

Explosive Output Testing. Under this title V.J. Menichelli briefly describes in Ordn 48, 663-66 (i 964), the following tests for detonators; Trazul Test, Sand Bomb Test, Steel Dent Test and Lead Disk Test.
See also the following reports describing expl output testing fixtures & procedures:
c) E.R.Lake, "Percussion Primers, Design Requirements", McDonnell Douglas Corp Rept MDC A0514, St. Louis, Missouri (June 1970), p 7 (output characteristics)

Explosiveness of Ammonia-Oxygen Mixtures, Danger of. A dry mixture of ammonia and air is capable of detonating at 0° over the range 15.5 - 27.2% ammonia, by vol, and at 100° over the range 14.5 - 29.5%. In moist air, however, the danger decreases with increasing temperature; at 0° the detonation range is 15.5 - 27%, at 40° it is 20-25%, and over 45° there is no tendency to explode. The stoichiometric mixture is 22% ammonia, 78% air, and has a def vol of 0.5 m/sec. At 18° the detonation range for ammonia/oxygen is 16.7-79 vol % ammonia; by 100° the lower limit has fallen to 16% ammonia
Ref: E.Banik, Explosivstoffe 1957, 29-32 and 1958, 145-47 (7 refs)

Explosiveness and Constitution. According to Majrich, the explosiveness depends not only on the nature of the carbon chain, but also on other groups. For instance the aldehyde, keto and carboxylic groups lower the brisance, sensitiveness and stability, especially in nitric esters and the stability seems to increase with increasing mol wt
Ref: A. Majrich, Chem Obzor 7, 104-8, 117-119 (1932) & CA 26, 5209 (1937)

Explosive Nitric Esters, Liquid. Spout wash water formed in the mg of liquid expl nitric esters is treated with a non expl aromatic nitro hydrocarbon e.g. O-Nitro toluene (I), to extract the expl esters and render the wash water safe for disposal. Wash water from a Nitro glycerine (II) plant contg 0.35% II was treated at a rate of 25000 lbs/8 hrs with 1000 pounds of (I) which was continuously recycled so as to give a 2:1 wash water: expl vol ratio
Ref: W.G.Allan et al, Brit P734523 (1955) & CA 50, 2177 (1956)

Both expls are stable in storage at 80 to 120° F. They are used as hose fillers for mine field clearance

**NOTE:** See also Vol 4 of Encycl, pp D1084 ff (Output Tests)

**Explosive Papers or Pyropapers** (Papiers explosibles or Papier fulminants in French; Papel explosivo, in Span). Under these names are known absorbent (such as filter) papers impregnated by solutions of various substances and then dried. They served as basis of several propellants and expls.

Daniel (Ref 1, p 599), under the title *Papier explosible* describes an expl prep by impregnating filter paper with aqueous suspension of saltpeter 41.66%, K chloride 41.66%, charcoal or coal dust 8.34% & sawdust 8.34%, followed by drying; some glue was dissolved in water to make the suspension adherent to the paper.

Reichen was the first to utilize explosive paper as a basis for expls. He patented in 1865 in England an expl which he called Meland (Papier-poudre), instead of calling it Reichen poudre (Ref 1, p 436).

One of the expls utilizing "explosive papers", Dynamogene, described in Ref 1, p 231-32, is also described in Vol 4 of Encycl, p D1740-R

Other expls and propellants based on expl paper are: Gelbhte (described under Emmens in Ref 1, p 257); Hochstädtter (Ref 1, p 376); Meche lente (Ref 1, p 433; Peley (Papier explosible) Ref 1, p 602; Prentice (Ref 1, p 651); Pyropapier (Ref 1, p 665); Reichen (See Meland, Ref 1, p 436); Spiralite (Ref 1, p 735); and Unionite (Ref 1, p 779)

All above substances will be described later.

Pérez Ara (Ref 2), under the name *Papel explosivo de Pelex* describes an expl prep by wetting an ordinary blotting paper in aqueous syrupy suspension contg: K chloride 45.5, K ferrocyanide 11.5, Na chloride 24.5, charcoal 11.5 & starch 7.0%. This comp is similar to that of Peley (Papier explosible) given by Daniel (Ref 1, p 602) as: K chloride 47.50, K ferrocyanide 12.42, Na chloride 24.82, charcoal 8.17 & starch 7.09%


**Explosive PB-RDX.** See Explosive Composition PB-RDX

**Explosive Pentolite.** See Explosive Composition Pentolites

**Explosive Performance, Comparison of Two Methods for Its Evaluation.** Until the middle of 1950's, the choice of expls for blasting a particular rock was based on the basis of the following methods: a) Trial and error gained from previous experience in similar rocks; b) Calculation of meaningful performance parameters of expls from their chemical compns by means of laws of thermodynamics; or c) Laboratory determination of expl characteristics.

Although good results have been obtd with expls chosen on the basis of these methods, it was not unusual to find quite different expls being used in very similar rocks.

In 1956, Duval & Atchison of US BurMines (Ref 1) developed an experimental technique for making quantitative measurements of the strain produced in a solid rock medium by the deton of an expl chge. This technique has been used to study the physical process of rock breakage. The studies have shown that the characteristics of the strain pulse produced in a rock by an expl determine the effectiveness in breaking rock. Thus, the strain-measuring technique provides a direct method for measuring the relative effectiveness of different expls (Refs 1, 3 & 7)

The Spencer Chemical Co, Kansas City, Missouri, thru a contract with the Armour Research Foundation, was working on an underwater testing method for evaluating the relative effectiveness of different expls by measuring the pressure produced in the water by the de-
The detonation of small expl. charges (Ref 6). The method was simpler and cheaper than making strain measurements in rocks and provided conditions somewhat closer to deton in rock medium than many other types of performance tests. However, the differences in conditions were still great enough to raise questions about predicting expl performances in rock from performance in water.

The purpose of the tests described on the paper of Missouri School of Mines (Ref 7) is to help in predicting expl performance in rock from performance in water. Four expls were tested both in water and in rock so that direct comparison of the results of the two methods of testing could be made. The rock tests were made at a granite quarry operated by the Consolidated Quarries Division of the Georgia Marble Co., near Lithonia, Ga. The rock was uniform in sp gr ca 2.6 and propagation velocity of about 18000 ft/sec. The underwater tests were made in a deep pond at the Armour Foundation test facility near Coal City, Illinois. Water had sp gr 1.0 and propagation velocity 5000 ft/sec.

The expls tested were: a) HP-G-Hercules 60% High Pressure Gelatin (initiated by No 6 Blasting Cap); b) N-IV-Spencer N-IV AN-FO expl consisting of 94/6-An prill-Fuel Oil mixture with a small amt of surface-active agent to prevent caking (initiated to high-rate underwater detonation by No 6 cap and 36-inch long 400-grain Primacord); c) M-H-Spencer M "N" AN-FO expl consisting of 94/6-AN/prill/Fuel Oil with 3% diatomaceous earth added as coating to prevent caking (initiated by N-IV expl to high-rate detonation); d) M-L-Spencer M "N" AN-FO. Same as M-H but initiated with No 6 cap and 12-inch of 400-grain Primacord in order not to produce high-order detonations. Eight pounds of expl charges were used in all of the tests except some of the High Pressure Gelatin shots in the underwater tests were 1.3 pounds.

The strain measurement test set-up consisted of linear array of shot and gage holes, as shown in Fig Ex 15. The holes were drilled in solid rock about 25 ft deep and at a distance from any free face, so that charges detonated at the bottom of the shot holes did not produce surface breakage, and so the gages cemented in the bottom of the gage holes recorded the strain pulses produced in the rock without interference from surface reflections. Four holes at each end of the array were used as gage holes. Thus two shots with each expl were made in essentially the same rock and using the same gages. This provided sufficient information for a statistical analysis of the results.

Some details of the shot and gage holes are shown in Fig Ex 16. Eight pound charges loaded into 3-inch holes resulted in charge-lengths of about 2 ft for the Hercules HP-G charge and about 3 ft for Spencer AN-FO charges. Before being loaded each charge was weighed and divided into several small increments. A No 6 Blasting Electric Cap was taped to a piece of ¼-inch dowel, having the same length as the charge. For the AN-FO charges the Primacord booster was cut in short lengths and taped around the cap. To measure the rate of deton two targets were taped to the dowel, one about 3 inches above the cap and the other near the top of the dowel. A microsecond chronograph recorded the difference in arrival time of the deton wave at the two targets. The dowel was lowered to the bottom of the shot hole and held upright at one side. The HP-G charges were loaded by slitting 1½ by 8 inch sticks and tamping small increments in the hole. The AN-FO charges were loaded by pouring in small increments. Both types of expls completely filled the space at the bottom of the hole, and charges of sand was placed to stem the shot. Rock breakage was limited to a crushed zone seen in Fig Ex 16 in the immediate vicinity of the charge. After each shot the crushed zone was cleaned by blowing the hole with compressed air. Then the volume of the crushed area was measured by adding sand in known volume increments. The order of shooting was from the outermost shot hole in towards the gage holes, alternating from one end of the array to the other, so that for no shot was there any already broken rock between the charge portion and the gages.

The gage used to record the strain pulse produced in the rock was a radial strain gage consisting of a resistance-wire sensing element shielded with Cu and bonded to a short
LINEAR ARRAY OF TEST HOLES

FIG Ex15
FIG Ex16

DETAIL OF LINEAR ARRAY TEST
length of rock core. It was placed near the bottom of the gage hole, oriented to measure horizontal strain in the direction of the array of holes, and fixed in place with a high-strength cement. Cables led from the gages a distance of about 500 ft to recording equipment housed on an instrumental trailer. On each shot a recording was made from each of the four gages providing a strain-amplitude versus time plot of the radial strain at each gage position. From the records it was possible to determine the arrival time, amplitude and other characteristics of the strain pulse produced by each shot as a function of the travel distance of the pulse.

The underwater measurements were made using the following technique: expl chges were detonated at a depth of ca 25 ft in water ca 45 ft deep. Piezoelectric pressure gages were located at the 25 ft depth at distance of 25 and 50 ft from the chge (Fig. Ex 17). The location of the chges and the gages were chosen in the manner not to have reflections from the surface or the bottom interfere with the direct pressure pulse. The chges were prep'd by loading the expl, primed with No 6 Electric Blasting Cap and Primacord Booster if required, into waterproof plastic bags. Each chge was weighted with a bag of sand hung below the chge, and then lowered on a line to a desired position. Gage cables and fire line led about 500 ft to recording instruments located in a trailer. On each shot a pressure versus time recording was ob'td from each gage and each record made possible the determination of the amplitude, & other characteristics, and of the initial pressure pulse produced by the shot. By measuring the interval betw the primary and secondary pressure pulses, it was possible to determine the period of the oscillating gas bubble produced by the shot. The energy associated with the gas bubble was then cal'd from the period of oscillation.

More detailed description of experimentation is given in Ref 7 on which also are included several tables and charts. We are

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**FIG Ex17**

**UNDERWATER TEST SETUP**

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**LEGEND:**

o - EXPLOSIVE CHARGE

x - PRESSURE GAGE
giving here a summary of results which are in Table 4 of Ref 7, reproduced here as Table Ex7. This table shows relative values of the performance parameters for the four expls based on values for HP-G equal to 100. In comparing the results of the two test methods a reasonable criterion for determining significant differences among the parameters is a separation of at least two standard errors. With this in mind the following conclusions can be drawn: a) The various performance parameters took the expls in the same order of expected effectiveness, showing general agreement between the rock and water test methods. b) The underwater tests show a significantly greater difference between MN-H and MN-L than do the rock tests. The added confinement provided by the rock evidently caused the MN-L to detonate at or near its high rate, even though initiated with a small booster which produced a low rate of detonation in the water tests. This was confirmed by the nearly equal deton rates measured in the rock tests for the MN-H & MN-L. c) The peak strain produced in the rock showed a significant difference between the HP-G and the two fully-boosted AN-FO expls than did the peak pressure produced in the water. This difference may be explained by the different impedance ratios involved in the transfer of pressure from expl to rock and from expl to water. The differences in confinement provided by rock and water, and the differences in expl-rock and expl-water impedance ratios, must be kept in mind when predicting expl performance in rock from performance in water. Refs: 1) W.J. Duvall & T.C. Atchison, "Rock Breakage by Explosives", USBurMines Repr of Investigation R15356 (1956) 2) W.J. Duvall & B. Petruf, "Spherical Propagation of Explosion-Generated Strain Pulses in Rock", USBurMines R1 5483 (1959) 3) T.C. Atchison & W.E. Tournay, "Comparative studies of Explosives in Granite", USBurMines R1 5509 (1959) 4) D.E. Fogelson et al., "Strain Energy in Explosion-Generated Strain Pulses", USBurMines R15514 (1959) 5) T.C. Atchison & J. Roth, "Comparative Studies of Explosives in Marble", USBurMines R15797 (1961) 6) L.D. Sadwin et al., "Underwater Evaluation of the Performance of Explosives", Intl Symp Mining Research Rolla, Missouri, Feb 1961 7) T.C. Atchison, S.J. Porter & W.J. Duvall, "Comparison of Two Methods for Evaluating Explosive Performance", Intl Symp Mining Research, Rolla, Mo, Feb 1961

Explosive Phenomena and Detonation. See Detonation and Explosives Phenomena in Vol 4, p D346-R

Explosive Picratol. See Explosive Composition Picratol

Explosive Pipe. See under Explosive Rivets

Explosive Pipe Closure System. A fast, high-strength mechanism for closing off inaccessible pipes is explosively actuated. The system, devised to protect instrumentation mounted in pipes from flying debris during underground nu-
clear testing can also be used to close oil well casings or other pipes in hard-to-reach locations. A 4-inch ID pipe was closed in 200 microseconds. By comparison, conventional mechanical valve closures require a longer actuating time, particularly as the pipe diameter increases.

The design consists basically of a tubular steel section of pipe with a malleable metal liner on the inside and an expl assembly on the outside (Fig Ex 18). Detonators initiated at opposite sides of the expl initiate a detonation wave along two line-wave generators to a cylindrical expl collar located beneath a lead tamper. The expl then generates a radial shock wave that causes the pipe and liner to implode and close. The pipe wall is thicker at the point where the cylindrical expl charge begins, tapering down to the minimum pipe diameter. The expl cross-section also thins as it approaches the thinner portion of the pipe wall. These two features prevent the liner from breaking up before a complete closure is achieved. The design specifies that the length of the explosive collar should be about 2.5 to 3 times the diameter of the pipe aperture, and that the pipe taper length should be 1.5 times this diameter. For every square inch, the expl content of the cylindrical charge should range from about 4 to 12 grams per square inch per inch of wall thickness.

Refs: 1) Sandia Laboratories, Albuquerque, New Mexico, 87115 2) G.Cohn, Edit, Expls & Pyrots 5 (5), 1972

**Explosive, Plastic.** See under individual names

**Explosive PLX.** See Explosive Composition PLX

**Explosive Power.** See under Explosive Properties and as Power of Explosive in Vol 1 of Encyc1, p XX

**Explosive Power vs Oxygen Balance, Correlation of.** The relationship of oxygen balance to expl power as measured by ballistic mortars has been studied empirically. Starting from modified oxygen balance developed for detonation velocity calculations, a numerical measure called the "power index" is derived which correlates closely the features of molecular structure with the power values. Expl power has also been expressed as an additive function of details of molecular structure. This is the basis for a method whereby power values may be derived which agree with experimental results to about 5%


**Explosive Press.** An explosively activated device by which materials may be compressed at pressures estimated at several millions psi. The presses may comprise either single or double-acting pistons. In a press consisting of a single-acting piston (Fig Ex 19), the sample is placed in the cavity of the lower platen. The steel piston is inserted on top of the sample and the upper platen is placed in position. A cylinder of high expl (Comp B) is placed at the center of the upper platen and detonated by a standard detonator. The piston is driven into the lower platen compressing the sample.

For higher pressures, double-acting pistons are employed (Fig Ex 20). In this press, the center plate has a lapped hole in which the pistons move. The sample is placed between the...
FIG Ex19. CROSS-SECTIONAL VIEW OF A SINGLE-PISTON PRESS

FIG Ex20. CROSS-SECTIONAL VIEW OF A DOUBLE-PISTON PRESS

2 pistons. Buffer plates are inserted between the pistons and expl charges. These buffer plates drive the pistons when the expl charges in the steel end plates are simultaneously activated.


Explosive Product Laser. The principle of using the products & energy from an expl as the medium for a laser pulse was studied by Hershkowitz & Lanzerotti (Ref 2) who also designed a laser detonation cartridge (LDC). The LDC uses the products from the deton of an expl whose composition, shape and mode of initiation were optimized. Interaction with a deformable wall directs the products thru convergent-divergent nozzles producing an inversion suitable for lasing.

Expls were chosen to approximate the known molecular requirements of a CO₂ laser. Product compn, temp & press were calc'd for an isentropic expansion from the Chapman-Jouguet detonation point (See Vol 14 of Encycl, pD231-R). Effective upper & lower CO laser level relaxation times for the products were calc'd and compared with flow expansion times to determine if inversion conditions were fulfilled. Results are presented for PETN, TNMe &
HNB, alone and mixed with Al. Predictions were verified by subsequent comparison with available exp1 data.

The expansion of products from an axisymmetric exp1 was calc using the HEMP computer program (See Vol 4, pD180 and Refs 12 & 15 under COMPUTERS), which gave data for the calc of further flow, and of the interaction of the products with the wall using the STROBE program. STROBE is a modification of a program written during investigation of muzzle blast (Ref 1).

It was predicted that an LDC with 30 g of exp1 in a 175 mm cartridge of 6 mm wall thickness and with an inner chamber of 120 mm max diam will provide 60 kilojoules total energy yield over a one millisecond duration in a pulsed flow mode.

Note: Lasers are briefly described under "Detonation, MASER AND LASER in" in Vol 4, pp D436-L to D441-L.


EXPLOSIVE AND RELATED PROPERTIES INCLUDING TESTS, OF EXPLOSIVES AND PROPELLANTS

1. Ability to Propagate Detonation or Transmission of Detonation. See Vol 1 of Encycl, pVII


3. Ballistic Mortar and Ballistic Pendulum Tests are listed under Power or Strength and briefly described in Vol 1, pp VII & VIII

4. Behavior Towards Flame and Heat. See under Sensitivity to Flame, Heat, Sparks, Electrostatic Discharge

5. Bichel Bomb Pressure Gage. See Vol 1, p VIII and in Vol 2, under Closed Bomb, pp C330 to C331

6. Blast Effect (BLE). It is the ability of an expl charge to destroy matter, or structures, located far from the site of expln.


Accdg to the late W.R. Tomlinson Jr. formerly of Picatinny Arsenal, blast effect is measured by the distance from burst, to which a certain type of damage occurs. Four types are distinguished a) Confined air blast; b) Free air blast; c) Underground blast; and d) Underwater blast.

Blast effect is such that, for an oxygen balanced expl, the heat of expln appears to be propagated thru the medium (such as air) in the form of a shock wave, or at least BLE-He (heat of explosion). For a negatively balanced compn, or one in which after-reactions (usually exothermic) can occur, BLE-He + A where A is the heat of the after-reaction.

In air, the after-reaction of most importance is the air-oxidation of unoxidized portions of the charge especially of the exothermic elements like Al. When the same elements are oxidized under water by CO2 or H2O, it is part of He.

Blast effects can be tested by various methods such as listed in Vol 2, pp B214-R & B215-L, under Blast Meters.

Blast Effectiveness of Various Explosives is given in Table on p B182 of Vol 2

Blast Effects Due to Reflected Shock Waves is given in Vol 2, p B182-L.

Blasting Action of High Explosives in Relation to Their Explosive Properties is discussed by Cook (1958), Chap 11, pp 265-82 (9 reps).


Blast Potential is discussed under Damage Potential of Air and Ground Blast Waves in Vol 3, p D3-R

7. Booster Sensitivity. It is the relative sensitiveness to an arbitrary graded series of boosters. One of its tests is briefly described in Vol 1, p8. As booster sensitivity is considered as one of the "Detona-
tion by Influence or Sympathetic Detonation”, described in Vol 4, pp 395-R to D398-R, it can be tested by the following method:

**Barrier Test** (Vol 4, p D331 & Fig 16)

**Card-Gap Sensitivity Test** (Vol 4, p D398-R)

**Card Test** (Vol 4, p D339-L)

Coefficient de self-excitation (CSE)-Fr test described in Vol 3, p C390-L

**Cylindrical, Gap Test** (Vol 4, p D333-L & Fig 19)

**Four Cartridge Test** (Vol 4, p 399-L)

**Gap Tests** (Vol 1, p XIV and in Vol 4, pp D303-R to D304-L)

**Halved Cartridge Gap Method** (Vol 1, p XIV)

**Large Scale Gap Test (LSGT)** (Vol 4, p D318-R & Fig 2 on p D319-L. Also p D324)

**NOL (Naval Ordnance Laboratory) Gap Test** (Vol 4, p 321-L & Fig 4)

**NOL Modified Gap Test** (Vol 4, p 327 & Fig 8 and pp D335-R & D336-L with Fig 26)

**Perpendicular Gap Test** (Vol 4, p 332-R & Fig 18)

**Shock-Pass-Heat-Filter (SPHF) Sensitivity Test** (Vbl 4, p D316 with Fig 1 and p D399-1)

**Small Scale Gap Test (SSGT)** (Vol 4, p D343-R & D344 with Fig 35)

**Three-Legged Table Sensitivity Test** (Vol 4, p D399-R)

**Wax Gap Test** (Vol 1, p VIII, under Booster Sensitivity and p A354, Note e, under Ammonium Nitrate. Also Vol 4, p D329 with Fig 13)

**Whole Cartridge Sensitivity Test** (Vol 4, p D399-R)

[See also AMCP 706-177 (1971), p 6]

**8. BRISANCE (B).** It is the ability of an expl charge to deform, fragment, or shatter matter at, or close to its surface.

A detailed discussion is given in Vol 2, under BRISANCE or SHATTERING EFFECT, pp B265-L to B266-R. Table 1 listed on pp B266 to B298 gives for numerous expls brisance tests in relation to TNT taken as 100. These tests include CCCCT-Copper cylinder compression test; FET-Fragmentation efficiency test; FGT-Fragment gun test; Kast’s Formula values; LBCT-Lead block compression test; PCCT-Plate cutting test; PDT-Plate denting test and ST-Sand test. References for these and some other brisance tests are given under “Brisance Test Methods” on p B299.

Two methods: “Strahlungsprobe” (Radiation Test) and “Stanzprobe” (Punch Test) are described on p B299.

The following brisance tests are described in Vol 1 of Encycl:

**Fragmentation Tests** (p XII)

**Fragment Gun Test** (p XII)

**Hopkinson Pressure Bar Test** (p XVI)

**Plate Denting Tests** (p XIX)

**Plate Tests** (p XX)

**Quinan Test** (p XXI)

**Sand Test** (pp XXI & XXII & PATR 3278 (1965), p 16

Modified Sand Test to Determine the Brisance of Liquid Explosives is described in PATR 3278 (1965), p 16

The following brisance tests are described in Vol 3 of Encycl:

**Closed Pit (or Chamber) Test and Other Fragmentation Tests**, which include:

- Closed Pit Test (p C346-L & Fig on p C347)
- Open Pit Test (p C346-R & C349-L)
- Panel Test (p C349 & Fig )
- Fragment Velocity Test (p C350-L)
- Low Panel Test (p C350-R)
- Silhouette Test (p C350-R)
- High Panel Test (p C350-R)
- Splitter dichteprobe (Fragment Density Test), (p C350-R)

**Compression (or Crusher) Tests**, which include:

**LCBT (Lead Block Compression Test)**, called in Ger Staubprobe nach Hess (Hess’ Crusher Test), uses apparatus “Brisance Meter of Hess” (p C492 with Fig). Its French version is known as Épreuve des petits plombs (Test with Small Leads) (pp C492-R & C493-L). Another Fz modification is Épreuve de Chalon (p C493-L). In the US modification of Hess’s method only one lead block is used. It is called Compression Test with Small Block (pC493-L). (Copper Cylinder Compression Test), called CCCT in Ger Staubprobe nach Kast (Kast’s Crusher Test), uses apparatus Bri-sance Meter of Kast (p C493-with Fig)

Compression Test of Quinan permits determination of not only brisance, but also of strength (potential) (pp C493-R & C494-L with Fig)

The following brisance subjects are discussed in Vol 4:
Brisance or Shattering Effect (pp D149-R & D150-L)
Brisance, Correlation with Chemical Structure (p D150-L&R)
Brisance, Correlation with Properties Other Than Chemical (p D150-R)
Brisance Determination by Method of Metal Acceleration by Explosives (pp D150-R to D152-R)

14. Brisance-Detonation Velocity Relationship is discussed in Vol 2, p B297. Table on p B298 gives for numerous expls, Brisance Density and Detonation Velocities called by the late W.H. Riskenbach and those taken from the literature.


14. Burning Rate, and Burning Rate Coefficient. See Vol 2, p B359-R

15. Burning Rate of Propellants as a Function of Pressure. See Vol 3, p C333 with Fig of pressure vessel


17. Calorimetric Tests. See Heat of Formation, Combustion, Deflagration, Explosion and Detonation

18. Capability to Inflame Test. French test known as Épreuve de l'aptitude de l'inflammation, described by L. Méfard, MP 33, 329-30 (1951)

19. Cavity Charge Efficiency. See Shaped Charge Efficiency

20. Characteristic Product of Berthelot or Force spécifique, in Fr. See Berthelot's Characteristic Product in Vol 2, pp B105 & B106-L


22. Closed Bomb (or Vessel) and Instruments for Measuring Pressures Developed by Explosives and Propellants. See Vol 3, pp C330-L to C345-R

23. Closed Pit (or Chamber) Test and Other Fragmentation Tests. See Vol 3, pp C345-R to C351-L

24. Coefficients d'utilisation pratique (CUP), (Épreuve de travail spécifique). French test for dem of power or strength. It is modification of Trauzl Lead Block Test. See Vol 1, pp IX & X

25. Combustion, Combustion Rates and Combustion Tests. See Burning or Combustion (item 11) and items 12, 14, 15 & 16


27. Concrete Test. See Vol 3, p C495-L

28. Cook-off Test of Spencer Chemical Co. See Vol 1, p A354, Note a

29. Covolume. See Vol 4, p D196-L


32. Crusher Tests. See Compression (or Crusher) Tests

33. CUP or cup. See Coefficient d’utilisation pratique

34. Dautriche Method. See Vol 3, p C311-R

35. Decomposition Temperature Test is described by A.J. Clear in PATR 3278 (1965), p 8

36. Deflagration Temperature Test. See Detonation (Explosion, Deflagration or Ignition) Temperature Test

37. Density Determinations are described in Vol 3, pp D64-R to D81-R

38. Detonability and Flammability of Explosives, Propellants and Pyrotechnic Compositions is discussed in Vol 4, pp D211-R to D213-R

39. Detonating Capacity of Explosives; Effect of Various Factors is discussed in Vol 4, pp D213-R to D216-R

40. Detonation (or Explosion) by Influence or Sympathetic Detonation. Its definition and description are given in Vol 1, p X and in Vol 4, pp D395-R to D398-R. Its tests are listed on pp D398-R to D402-L and also under Booster Sensitivity Tests.

41. Detonation (or Explosion) Pressure. Its definition is given in Vol 1, p X and description in Vol 4, pp D483-L to D485-R. It must not be confused with Pressure of Gases Developed on Detonation defined in Vol 1, pXX Experimental determinations of pressures developed on detonation or explosion are listed and in some cases, briefly described in Vol 4, D485-R to D491-R. More complete descriptions of some of these tests are given under "Closed Bomb (or Vessel) and Instruments for Measuring Pressures Developed by Explosives and Propellants", in Vol 3, pp C330-L to C345-R

42. Detonation Temperature. See Explosion (Deflagration or Ignition) Temperature. Not to be confused with Temperature Developed on Detonation or Explosion

43. DETONATION VELOCITY (Rate of Detonation or Velocity of Detonation) AND TESTS. Its definition and list of 14 refs are given in Vol 1, p X. A detailed discussion on this subject is given in Vol 4, under the following items:
   Rate of Detonation or Velocity of Detonation (pp D629-R to D640-R with 85 refs)
   Detonation Velocity, Anomalous High (pp D640-R to D641-L)
   Detonation Velocity-Charge Diameter Relationship (pp D641-L to D643-L)
   Detonation Velocity-Charge Density Relationship (pp D643-L to D646-L)
   Detonation Velocity - Charge Diameter and Density Relationship (pp D646-L to D654-R)
   Detonation Velocity and Chemical Composition and Detonation Velocity as a Function of Oxygen Balance and Heat of Formation (pp D654-L to D657-L)
   Detonation Velocity-Confinement and Obturation Relationship (pp D657-L to D660-L)
   Detonation Velocity - Critical and Limiting Diameter Relationship (pp D660-L & R)
   Detonation Velocity by Direct Visualization of the Explosive Flow (pp D660-R to D662-R)
   Detonation Velocity, Effect of Replacement of Air in Explosive Charges by Non-Explosive Liquids (pp D663-L)
   Detonation Velocity in Gases (pp D663-L to D666-L)
   Detonation Velocity, Influence of Ageing in Gelatin Explosives (pp D666-L to D667-L)
   Detonation Velocity, Influnence of Inert Components and Inert Additives (pp D667-R to D668-R)
   Detonation Velocity, Influence of Magnetic, Electro-Magnetic and Electrical Fields as well as of Electrons On (pp D668-R to D671-L)
Detonation Velocity, Influence of Method of Initiation (pp D671-L to D672-L).
Detonation Velocity by Metallic Transmission of Sulfur (p D672-L & R).
Detonation Velocity - Particle Size Distribution Relationship (pp D672-R to D673-R).
Detonation Velocity - Pressure Over Explosive Relationship (pp D673-R to D674-R).
Detonation Velocity - Temperature (Initial) of Charge Relationship (pp D674-R to D675-R).
Detonation Velocity, Experimental Procedures are listed in Vol 4, pp D654-R to D656-R and described in Vol 3, pp C310-R to C319-L under CHRONOGRAPHs. The following methods are included:
Dautriche Method (pp C311-R to C312-R).
Mettlegang Chronograph Method (pp C313-L and Fig on p C312).
Pin Chronograph Method (pp C313-R to C315-R).
Chronographic Method Employing Microwave Technique (pp C315-R).
Cook's Method, Pinset Diagram (p 316).

43a. Detonation Velocity - Brisance Relationship. See Item 8a: "Brisance - Detonation Velocity Relationship".

44. Explosion (Detonation, Deflagration or Ignition) Temperature. It is the temperature at which an explosive, propellant or pyrotechnic composition explodes, detonates, deflagrates or ignites within a definite time, say 0.1, 1.0 or 5.0 seconds. Various methods for its determination are briefly described in Vol 1, p XVI under Ignition (or Explosion) Temperature Tests. A detailed description of the test conducted at Picatinny Arsenal is given by A.J. Clear in PATR 3278 (1965), pp 7-8 with Fig. 8 on p 39. See also Vol 4, pp D390-R to D391-R and D583-L to D589-L.

45. Exudation (or Sweating) of Explosives. See Vol 1, p XI with 7 refs.

46. FI (Figure of Insensitiveness) Test. See Vol 1, p XII.

47. Flame Test. See Vol 1, p XII.


48. Flash Point. The lowest temperature at which a combustible or explosive liquid will give off a flammable vapor which will burn momentarily. It can be conducted in a closed or open cup (See under F's). Ref: CondChemDict (1961), 499-R.

49. Fragmentation Tests. See under BRISANCE and under "Closed Pit (or Chamber) Test and Other Fragmentation Tests" in Vol 3, pp C345-R to C351-L.

50. Friction Sensitivity. It is a measure of the resistance of an expl to friction, one of the properties required for determining safety in handling and transportation. Several methods for its determination are briefly described in Vol 1, p XIII.


52. Gas Pressure Developed on Explosion or Detonation is defined under Pressure of Gases Developed on Explosion or Detonation in Vol 1, p XX. See also under Detonation (and Explosion) in Gases in Vol 4, p D352.

53. Gas Volume Developed on Explosion or Detonation. See Volume of Gases Evolved on Explosion or Detonation in Vol 1, p XXVI.

54. Heats of Formation, Combustion, Deflagration, Explosion and Detonation. See Vol 4, Section 5, pp D369-L to D384-R.


59. Ignition Temperature. See Vol 1, p XVI and under Explosion (Detonation, Deflagration or Ignition) Temperature

60. Impact (or Shock) Sensitiveness. It is a measure of the resistance of expls to impact by a definite weight dropping from various heights. The test, known as Drop (or Falling Weight) Test serves to determine safety in handling and transportation. Its brief description is given in Vol 1, p XVII and in Vol 4, pp D391-R to D392. Another impact test, known as Bullet (or Rifle Bullet) Test is described in Vol 2, pp B332-L to B334-L with Tables on pp B335 to B339.

Note: A.J. Clear gives in PATR 3278 (1965) detailed descriptions of "Impact Test with Picatinny Arsenal Apparatus" (pp 2-4 with Fig 4 on p 35) and "Impact Test with US Bureau of Mines Apparatus" (pp 4-7 with Fig 7 on p 38). He also describes on p 7 "Modified Impact Tests for Liquid Explosives", made with US Bureau Mines and PicArsn Apparatuses.

61. Impetus and Available Energy in Detonation. See Vol 4, pp D391-R & D393-L

62. Impulse in Detonation. See Vol 4, pp D393-L to D394-L

63. Impulse Specific in Detonation. See Vol 4, p D394

64. Index of Enflammbility. See Vol 1, p XVII and AMCP 706-177 (1971), p 3


66. Initiating Efficiency. See Vol 1, p XVIII

67. Initiation Sensitivity. See Sensitivity to Initiation

68. Munroe-Neumann Effect Efficiency. See Shaped Charge Efficiency

69. Percussive Force of Explosives. See Vol 1, p XIX

70. Permissibility of Coal Mining Explosives is determined by submitting them to tests described in Vol 3, pp C368-R to C378-L. The galleries used for testing are briefly described in Vol 1, p XIV and more fully in Vol 3, pp C370-R to C378-R

71. Plate Tests. See Vol 1, p XX and under BRISANCE

72. Potential (or Effect utile). See Vol 1, p XX

73. Power or Strength. It is a measure of the capacity of doing useful work. It refers to both blast and propulsion, but power is normally used in military parlance, while strength by the commercial expl industry. See Vol 1, p XX and in Vol 4, pp D476-L to D479-R

Power or strength is usually deterged by one or several of the following tests:
- Ballistic Mortar (Vol 1, p VII)
- Ballistic Pendulum (Vol 1, VII & VIII)
- Cratering Effect (Vol 3, p C554)
- Quinan Apparatus (Vol 1, p XXI & Vol 3, pp C493-R & C494-L)
- Trauzl or Lead Block Expansion (Vol 1, p XXV)
- Mortar (Vol 1, p XIX)

74. Pressure of Detonation (or Explosion). See Detonation (or Explosion) Pressure

75. Pressure of Gases Developed on Explosion or Detonation. See Vol 1, p XX

76. Propagation of Explosion or Detonation. See Ability to Propagate Detonation or Transmission of Detonation in Vol 1, p VII

77. Propulsive Action (PrA) or Heating Action (Propulsive Force). It was defined by the late W.R. Tomlinson Jr, formerly of Picatinny Arsenal, as the ability of an expl or propellant charge to propel, or hurl matter or a projectile. This term has been used in industry to rate commercial expls and represents the same property as ballistic potential defines for propellants. PrA is proportional to the "hot-gas-volume" PrA = nRT, where n = gas volume per gram of the expl product at STP, R = gas cons-
tant and $T$ = absolute temperature. Tests which can be used:
Ballistic Mortar (Vol 1, p VII)
Ballistic Pendulum (Vol 1, p VII)
Mortar (Vol 1, p XIX) [Barnett (1919), 181-82]
Note: Accord to L.V. Clark, IEC 25, 1388 (1933),
the relative propulsive strength can be determined
either by Ballistic Pendulum Test or
Trazol Test, usual tests for power determination.
The Pb block compression value is regarded as
a measure of relative brisance while Fragmenta-
tion tests in hand-grenade bodies measure
relative shattering power

78. Quickness (Vivacité en Fr) of Burning of
Propellants Determination. See H. Muraoir
"Poudres et Explosifs", Paris (1947), 90-92
and also his papers published in MP and MAF

79. Resistance to Heat Tests (Épreuves de
la résistance à la chaleur). French "official"
described in book listed in Vol 1, p XXI

80. Rifle Bullet Test. See Bullet Impact Sensi-
tiveness Test

81. Sand Test and Sand Crushing Test. See
Vol 1, p XXI & XXII and under BRISANCE

82. Sensitivity to Detonation by Initiating
Agents. See Sensitivity to Initiation

83. Sensitivity to Electrostatic Discharges.
See "Electrostatic Sensitivity Test" in PATR
3278 (1965), pp 14-15 and Fig 13 on p 44 and
also "Sensitivity to Initiation by Electrostatic
Discharge " in AMCP 706-177 (1971), pp 9-10

84. Sensitivity to Flame, Heat and Sparks.
See Vol 1, pp XXII & XXIII

85. Sensitivity to Impact. See Impact Sensi-
tivity

86. Sensitivity to Initiation by Primary Expls-
osives, Detonators and Boosters. It can be ex-
pressed as the minimum weight of an initiating
expl or the No of detonators to cause a com-
plete detonation of a HE (high expl). See Vol 1,
p XXIII and under Detonation, Sensitivity of Expl-

osives to, in Vol 4, pp D511-R to D515-R. See
also A.J. Clear, PATR 3278 (1965), pp 9-11:
"Sensitivity to Initiation as Determined by Sand
Test" and on pp 12-14: "Sensitivity to Initia-
tion by the Modified Sand Test for Liquid Explo-
sives"

87. Shaped Charge Efficiency. See Vol 1, pp
XXIII and under Detonation, Munroe-Neumann
Effect in Vol 4, pp D442-R to D454-L

88. Stability and Instability of Explosives
are discussed in Vol 4, pp D569-L to D574-L.
The so-called Thermal Stability can be detd
by the following Heat Tests:
Abels or KI-Starch Test (Vol 1, p A2-L)
Angeli's Test (Vol 1, p A403)
Bergmann-Junk Test (Vol 2, pp B102-R &
B103-L)
Brame's Test (Vol 2, p B260)
Brunswig's Test (Vol 2, p B319-L)
Chiaraviglio & Corbino's Test (Vol 2, p C179-L)
Desmaroux's Test (Vol 3, p D90-R)
German 132° Test (Vol 1, p XV)
Heat Tests at 100°, 120° & 134.5° (Vol 1, pp
XV & XVI)
International Test at 75° (Vol 1, p XVIII)
Resistance to Heat Test (Vol 1, p XXI)
Silvered Vessel Test (Vol 1, p XXIV)
Surveillance Tests at 65° & 80° (Vol 1, pp XXIV)
Taliani's Test (Vol 1, pp XXIV, XXV)
Vacuum Stability Tests (Vol 1, p XXVI)

Several tests which are listed in Vol 1,
p XV under Heat Tests (Thermal Stability Tests)
are described in books of Reilly (1938) and
Barnett (1919). These tests are not used in
USA

A detailed description of the following sta-

bility tests are given by A.J. Clear in PATR
3278 (1965):
75° International Test (p 18),
82.2°C KI Test (p 19)
100°C Heat Test (p 19)
90°, 100° and 120° Vacuum Stability Tests (pp
19-22 and Figs 15, 16, & 17, pp 46-48)
65.5° Surveillance Test (pp 22 & 23 & Fig 18 on
p 49)
80° Surveillance Test (p 23)
120° and 134.5° Heat Tests (pp 23 to 25)
Taliani's Test (pp 25 to 27 & Fig 19 on p 50)
65.5° KI Test (pp 27-29 & Fig 20 on p 51)
89. **Strength of Explosives.** See Power and Strength of Explosives

90. **Surveillance Tests.** See under Stability and Instability and in PATR 3278 (1965), pp 22 & 23

91. **Sympathetic Detonation.** See Detonation by Influence and also under Booster Sensitivity

92. **Taliani Test.** See Vol 1, p XXIV & XXV and under Stability

93. **Temperature of Detonation or Explosion.** It is the temperature developed on detonation or explosion. It must not be confused with Explosion (or Ignition) Temperature, listed here as Item 11.

   It is listed in Vol 1, p XXV in which are 8 refs describing the tests.

   In Vol 4, under "Detonation (and Explosion) Temperature Developed On," pp D589-L to D601-L are described the methods of its calculation and several methods of experimental determinations, which include spectrographic method, optical pyrometer and spectra of luminosity obtb by radiation from detonated charges (pp D592-R to D596-R). On pp D596-R to D597-R are listed the following methods: thermocouples, resistance thermometers, pyrometric cones, photography, X-rays, pyrometers, ionization of gas, electron temperature, band spectra, line reversal, spectral distribution and photomultiplier color pyrometer, image converter pyrometer and image opticon spectrograph.

   On p D597-R of Vol 4, is briefly described a "Self-Calibrating High-Speed Photographic Pyrometer" devised by J. Tyrone of PicArsn. On pp D597-R & D598-R is abstracted the paper of F.C. Gibson describing the method developed at BuMines. On p D598-L is briefly described the "Spectroscopic Method" developed in Russia by F.A. Baum et al. On pp D598-R & D600-R Ref 46, is described "Color-Optical Method" developed in Russia by L.M. Voskoboinikov & A.Ya. Apin

94. **Transmission of Detonation.** See Ability to Propagate Detonation in Vol 1, p VII

95. **Trauzl Test of Lead Block Expansion Test.** See Vol 1, pp XXV & XXVI

96. **Vacuum Stability Tests.** See Vol 1, p XXIV and in PATR 3278 (1965), pp 19-22 & Fig 16 on p 47

97. **Vapor Pressure.** Its value, usually expressed in mm of mercury column, gives an idea of volatility, and in some cases of stability. Experimental determination is given in Refs listed in Vol 1, p XXVI

98. **Velocity of Detonation Tests.** See DETONATION VELOCITY TESTS

98a. **Velocity of Detonation-Brisance Relationship.** See Brisance-Detonation Velocity Relationship

99. **Volatility of Explosives.** See Vol 1, p XXVI

100. **Volume of Gases Evolved on Explosion or Detonation.** See Vol 1, p XXVI and its six refs

**Explosive Properties and Decomposition of Copper Derivatives of Acetylene Hydrocarbons** are described by I.M. Dolgopol'skii et al., J Appl Chem (Russian) 19, 1281-90 (1946) CA 41, 6721-22 (1947)

**Explosive Properties of Initiating Explosives** are discussed by A. Suzuki in J IndExplosSoc Japan 14, 162-63 (1953) & CA 49, 11381-82 (1955)

**Explosive Properties of Mixtures of Organic Substances with Nitric and Perchloric Acids** are discussed by L. Andrussov in Chim et Ind (France) 86, 542-45 (1961) and in Explosivstoffe 1962, 153

**Explosive Properties**, including a Blast Test are discussed by H.L. Heman, PATM 1459 (1964) (Cont)
Explosive PTX-1 and PTX-2. See Explosive Compositions PTX-1 and PTX-2

Explosive PVA-4. See Explosive Composition PV-4

Explosive Reactions. Many chemical reactions are explosive and some of them are dangerous.

For example: 1) P. Nawiasky et al., reported in C&EN 23, 1247 (1945) that extremely briskan expl oils were formed when diazotized 4-chloro-o-toluidine was treated with sodium mono- or disulfide
2) H. H. Hodgson, Chem & Ind 1945, 362 described explosive reactions of diazonium c ompound with sulfides of sodium. He claimed that he prepd as early as 1918 a brilliant red solid which exploded violently on rubbing with a glass rod, when he treated diazotized o-nitro-aniline with N disulfide. He also listed sever al later refs in which expl reactions between diazotized compd and sulfides were reported. Some of these expl products were known in USA as "explosive diazo-sulfides"
3) A. I. Vogel, Practical Organic Chemistry", Longmans Green, London (1948), 573 stated that reactions between Na2S and some diazonium compounds might lead to formation of violently explosive diazosulfides and related comounds. The following reactions with Na2S are known to lead to dangerous explns: diazotized derivatives o-nitro-aniline, of m-chloroaniline, of 4-chloro-o-tolu- dine and of 2-naphthylamine
4) R. C. W. Hollingshead & P. E. Garner, Chem & Ind 1953, 1179-80 drew attention to previous reports on expl nature of the reaction betw certain diazotized substituted benzenes and Na polysulfide and stated that not all the reactions lead to the formation of such comounds. For example, when diazotized anthraquinone was treated with Na polysulfide (as in common use in the dye industry), no formation of expl products was ever observed. H. & G. warn, however, that in dealing with other diazonium-polysulfide reactions extreme caution must be observed
5) H. Lindlar, Angew Chem 75, 297-8 (1963), reported an attempt to destroy left over di- methyl sulfate with concd ammonia resulted in an expln, while portionwise addition of dil ammonia was uneventful
6) K. A. Jensen et al., Acta Chem Scand 18 (3), 825 (1964), reported that the reaction of nitrous acid at 0°C with methylthiocarbonylhydrazine (HCONCSNH2) gave 5-methoxy-1,2,3,4-thiatriazole S-N=N-N=O(CH3), which exploded at room temperature. Higher alkyl derivatives were unstable
7) J. Kharasch, JACS 72, 3322-3 (1950), reported that 2,4-dinitrobenzenesulfenyl chloride, (O2N)2C6H2S(OCl), will expl if prepd at a temp over 30-40°C
8) Anon., ChemEng News 35, (47), 57 (1957), reported that benzenesulfenyl chloride itself exploded after months of storage in glass at room temp
9) I. B. Douglass & D. A. Koop, JOC 29 (4), 951-2 (1964), reported that CH3SOCl exploded after months of storage in a sealed ampoule at room temp, probably because of a slow disproportionation to CH3SO2Cl and CH3SCl, the latter being unstable
10) Highly fluorinated comounds are extremely dangerous and may react with things which are normally considered "neutral" outside the field of fluorine chemistry. Consider the following examples, presented in chronologica l order: a) A. G. Sharpe & H. J. Emeleu, JCS 1948, 2135-8, reported that Br2 reacts violently with NH4F, NH4Cl, KBr & KI b) A. Kennedy & C. B. Colburn, JACS 81, 2906-7 (1959) warned of the expl nature of HNF2 either solid or liq c) R.N. Haszeldine & F. Nyman, JCS 1959, 1084-90, reported that chlorotristifluoroethene (chilled) ignites in the dark in an oxygen atmosphere when chlorine is introduced, but an expln occurs when bromine is added under the same conditions d) C. B. Baddiel & C. G. Cullis, SympCombust, 8th, Pasadena, Calif 1960, 1089-95 (Publ 1962), reported that ClF3 ignites methane at ambient temp when the ratio of the two is 2:3, and at even lower ratios as the temp is raised; ignition of propane occurs at temps 25-35°C lower than with methane at a corresponding pressure but is less violent e) E. D. Whitney et al., JACS 86 (13), 2583-8 (1964), reported violent reactions with water and explns with common organic solvents when mixed with any of the following: KClF4, RbClF4, CaClF4, KBrF4, •
& CsBrF₆, k) K.J. Martin, JACS 87 (2), 394-5 (1965), warned of the expl nature of HNF₂. g) K.I. Metz, ChemEngNews 43 (7), 41 (1965), reported that OF₂ will expl when dispersed on 60-80 mesh SiO₂ when confined in a tube less than 5mm ID at a temp exceeding 77°C and a pressure of 254mm Hg. h) A.G. Streng and F.I. Metz, in separate articles, ChemEngNews 43 (12), 5 (1965), reported that OF₂ and water is highly expl and that OF₂ dispersed on silica is particularly expl when confined in tubing of, or less than, 3mm in diam. i) W.D. English & D.R. Spicer, CryogTechnol 1 (6), 260 (1965), reported that liq F₂ on ice at -320°C is impact sensitive and will expl. The danger here is in allowing water into cryogenic systems containing F₂.

11) Another compd shown to be unexpectedly hazardous is dimethyl sulfoxide (CH₃)₂SO or DMSO. The following chronological reports, some "useful", will serve as examples: a) S.A. Heininger & J. Dazzi, ChemEngNews 35 (9), 87 (1957), reported that DMSO decomposes violently when mixed with acyl halides in general, and these in particular: acetyl, benzene-sulfonyl, benzoyl, cyanuric, also thionyl halides, phosphoryl chlorides and PCl₅. b) H. Ratz, Ger P1092358 (1960), reported that 1:1 DMSO:NaClO₄ or 1:1:1 DMSO:NaClO₄·H₂O forms a solid when melted together which is a suitable matrix for Hexogen or NGO/Al. c) P. A. French, ChemEng News 44 (15), 48 (1966), reported that the attempt to dissolve NaH in DMSO at 70°C resulted in a sudden rise in temp following an explin just as solution was complete. d) G. L. Olson, ChemEng News 44 (24), 7 (1966), reported the same as in the preceding item, except that the temp was only 50°C and only half as much NaH was involved - in either case the DMSO being in excess over the NaH for the reaction DMSO+ NaH= Na⁺DMSO⁻+H₂. e) G. G. Allen et al., ChemInd (London) 40, 1706-7 (1967), reported that DMSO explodes with acyl chlorides, aliphatic or aromatic, also SOCl₂, POCl₃ & P₂O₅. f) J. M. Rowe et al., JACS 90 (7), 1924 (1968), reported that DMSO may explode when mixed with HIO₄. The only safe procedure is to add small amounts of HIO₄ to DMSO with good stirring. g) H. Dehn, Brit P1129777 (1968) and USP3463684 (1969) reported that DMSO can be made to replace some or all of the six waters of crystallization in iron or aluminum nitrates and perchlorates. The resulting material is an expl whose energy release will depend upon the actual number of waters displaced and the salt involved; the addition of AN improves the energy release; also functional as water displacers are methylthiethylsulfoxide, ethylpropylsulfoxide, and methylidimethylaminomethylsulfoxide.

Explosive (or Detonative) Reactions, Theories of. See under Detonation (and Explosion) Theories in Vol 4 of Encycl, pp D601-D629. The different theories are listed on pp D601 and D602.

See also the following refs
(1936) (Explosive reactions) 14) D.A. Frank-Kamenetskii, ZhFizKhim 10, 365-70 (1939); 16, 357-61 (1942) & 20, 729-36 (1943) (Mathematical theory of thermal expln, called "stationary theory of thermal expln") 15) K.K. Andreev, KhimReferatZhur 1940, No 10-11, p 129 & CA 37, 1604 (1943) (Mechanism of expl reaction)

**Explosive of Rinenbach & Carroll. See Explosive Composition of Rinenbach & Carroll**

**Explosive RIPE. See Explosive Composition RIPE**

**Explosive Rivets or Other Fastening Devices.** (These devices may include bolts, boars, pins and rods). In the usual process of riveting, a red hot rivet (which is a short cylindrical piece of steel with a head on one end), is set in a hole drilled (or punched) thru plates required to be joined. This is followed by sharp blows on the headless end of the rivet with a hammer (while the rivet is still hot) until the second head is formed. During this operation the opposite end to that being struck is backed-up by the sledge hammer held against it. This method is slow and cannot always be used; for example, when joining plates which can only be reached from one side.

The expl rivets, invented about 1940, are great time savers and can be used anywhere.

Essentially the expl rivet is an ordinary rivet having a cavity in the end opposite to the rivet head. The cavity is filled with a small quantity of expl of the initiating type. The rivet (or other fastening device like, bolt,
bar, pin, rod, etc) is driven cold into the hole between two metal pieces to be joined and then the rivet is heated to the temp required to detonate the expl charge. This crimps the headless end and sets the rivet properly.

In the original method for initiating the charge, the head of rivet was heated with a device resembling a soldering iron and heat was transmitted thru the metal of the rivet to the opposite end where it detonated the expl charge. This heating device was improved by L.A. Burrows et al (Ref 3) of the DuPont & Co and it could heat the rivet to 100-150°. This method however, had some disadvantages. Much more heat, for example, was required for bringing about ignition in some cases, where a number of rivets were to be heated and where an oxide coating on the rivet head decreased the rate of heat transfer to the metal surface. Another disadvantage came from the fact that with some expl mixts rivets had to be overheated in order to bring about the detonation and this caused corrosion of the rivet. In order to overcome these disadvantages, Burrows et al (Ref 4) proposed a device in which heating was due to induction by high frequency currents, up to 10000 kilocycles. In order to generate such currents, an electron vacuum tube oscillator was used. Other methods for generating high-frequency currents included spark-gap oscillators, various types of electromechanical oscillators or various types alternators.

In cases when electrical current is not easily available, as for example, in field work, ignition can be accomplished by fuse, percussion, or by an especially designed fuel torch with narrow flame, which heats only a very small area of the rivet (Ref 6).

The most convenient method of ignition, however, seems to be by means of an electrical conductor introduced into the cavity of rivet (or other connector element, such as bolt, bar, pin rod, etc), and connected to a source of relatively high voltage electricity. The inserted conductor is insulated except at its terminal point. With this conductor sufficiently close to the bottom of the rivet cavity in the vicinity of the expl charge, the circuit may be closed by throwing of a switch. This will cause a spark to jump across the gap between the conductor and the metal of the rivet, thereby bringing about the ignition and deton of the expl charge in the rivet. This method is described more fully in Ref 4 and expls used with this method of ignition are listed in Ref 5.

A new type of rivet, Fig Ex21, patented in 1951 by Burrows et al (Ref 9) had a cavity extending longitudinally thru a substantial part of the shank and usually entering from the shank end. The diam of the cavity at the shank end was 0.4 to 0.6 of that of the shank diameter, while at the extended portion it is 0.2 to 0.4.

The charge of expl (such as a mixt of Hexanitromannite 27, Tetracene 25 & Al powder 48%) was so loaded that the increment in the main cavity was at least beyond the outer surface of the 2nd sheet to be joined. The portion of expl in

![FIG. Ex21](image_url)

reduced diam in the cavity extension served to blast the metal into right connection with the walls of the hole thru which the rivet was inserted.

Numerous compds and compns were proposed for using in expl rivets. One of the earliest compds suggested was LA, but it was found to be unsuitable on account of too high temp of ignition (about 330°). For this reason the Dynamit AG (Ref 1) proposed to lower the flash point by mixing it with one of the following compds: Diazobenzene Nitrate (fl p 90°); Chlorodinitrodiazophenol (fl p 120°); Dibromodiazophenol (fl p 142°); Nitrodiazophenol (fl p 142°); Diazobenzensulphonic acid (fl p 150°); Silver Acetylide (fl p 150°); Copper Acetylide (fl p 150°) or Guanilnitrosaminguanyltetracene, known as Tetracene (fl p 144°). E.R. von Herz et al (Ref 2) proposed a mixture congn 85-90% of LA with 10-15% of Tetracene. The mixt ignited at 145-150°. Inert substances
could be added to diminish the brisance of the above mixture.

Burrows and collaborators of DuPontCo, patented numerous mixtures for use in expl rivets which were suitable for use in expl bolts, bars, pins and rods. It was claimed that expls used in expl rivets, or similar devices, should possess a velocity of detonation above 1000m/sec. To these belong MF, LA, DAzDNPh, Tetryl, PETN, HeN Mannitol, etc. As these expls require fairly high temps for their ignition, easily ignitable expls, such as primary expls: LSt, Cu Acetylide, etc must be incorporated. For example a mix of LA 70, Tetryl 10 & LSt 20% can be used in expl rivets, fired either by heating method, or by the spark produced by the electrostatic discharge method using a charge preferably below 100000 ergs.

In order to determine which expls are capable of ignition by an electrostatic discharge of an energy amounted to 100000 ergs, or less it is necessary to subject each prospective expl to the following "energy requirement test". For this a layer of the expl is spread in thickness of 0.016 inch on a steel plate and is separated by a a short gap from a steel needle. This needle is so arranged that it can be thrown into a closed circuit with a condenser of known capacity, on which a controlled voltage can be imposed. In this way a spark of the desired energy content can be caused to jump the gap from needle to the plate at the locus of the expl layer. Operating accdg to this arrangement, approximate electrostatic energy requirements in ignition of various expls were determined as follows: LSt <500, Cu Acetylide <500, and Pb Nitratohypophosphate <500. Other expls fulfilling the energy requirements are Silver Azide, Basic Lead Picrate and Lead Nitratophosphate. LSt required >200000 energy and although unsuitable by itself could be used in mixts with substances such as LSt.

Note: Although most of these expls can be detonated by static charges such as can be accumulated by human bodies, there is no danger of using these expls in metallic rivets. As these rivets are good conductors, no static accumulation is possible in the vicinity of the expl charges.

In the last patent before Burrows' death (Ref 9), the following compns for expl rivets are listed:

a) LA 90 & Tetracene 10%
b) HeN Mannitol 27, Tetracene 25 & Al powder 48%

With these charges densities of 1.6 to 1.9 g/cc can be satisfactorily used. The amt of expl chge for optimum results will depend on the nature of the expl, the size of the rivet, and the material of which the rivet is constructed. For example, with an Al rivet having a recess of 0.1 inch diameter, a 0.4 grain of LA-LSt would be satisfactory while with larger rivets and the increased size of cavity, as much as 4 grains might be required.

For loading a rivet, the expl is introduced into the bottom of the recessed cavity and then the opening is closed. The method preferred by Burrows and collaborators, consists of preparing a jelly by mixing the expl compn with NC gelatinized by a volatile solvent (such as amyl acetate) and then extruding this jelly into place in plastic form in a thin-walled collapsible tube. The extruded mass remains in place where deposited and hardens on subsequent evaporation of solvent. Since hardening or setting requires a certain interval of time, the loading of the rivets should preferably be done prior to their insertion into the objects to be rivetted. In the case of large rivets or fasteners, it is desirable first to charge the expl into a cylindrical metal shell and then to introduce the shell, prior to firing, into the cavity of a rivet. (See also Ref5)

Refs: 1) Dynamit AG BritP 528299 (1941) & CA 35, 7716(1941) (Detonating charges for expl rivets) 2) E.R.von Herz et al, GerP 702269 (1941) & CA 35, 8299 (1941) (Detonating charges for expl rivets) 3) L.A.Burrows et al, USP 2295075 (1942) (Portable heating device for firing expl rivets) 4) L.A.Burrows et al, USP 2327763 (1943) (Improved method of firing the expl charge in expl rivets) 5) L.A.Burrows, USP 2387742 (1945) (Several novel types of expl rivets are described. Application of the principle of using expls not only to expl rivets, but to any expl metal connecting element (such as bolts, bars, pins & rods) for fastening one or more articles. Also a list of expl compns used in expl rivets is given) 6) L.A.Burrows
USP 2388901 (1945) (Heating device, resembling torch used by welders, for ignition of expls in rivets) 7) L.A. Burrows & W.E. Lawson, USP 2410047 (1946) (Various expl rivets and other explosively bursting joints) 8) F.F. Huston et al, USP 2412886 and 2412887 (1945) (Application of the principle of expl rivets in the construction of locomotive boilers. It is claimed that completely fluid-tight joints may be produced by expanding the ends of stay bolts thru the use of expl charges) 9) L.A. Burrows & W.E. Lawson, USP 2556465 (1951) (Improvements in explosive rivets and in charges used in them) 10) E.R. von Herzen, Explosivstoffe 1954, 29-38 (Expl rivet called in Ger Sprengpist contained Hexanitromannitol 25, Tetracene 10 & Al powder 65%. Several figs. are included in paper) 11) J.T. Tsukii & S. Kikuchi, Jap P4443 (1954) & CA 49, 10628 (1955) (Comps used in expl rivets: Diazo-dinitrophenol 60 and Tetracene 40%; Diazodinitrophenol 60, Tetracene 20, and Hexogen or Nitroguanidine 20%. Oxidizing agents such as KClO₃ or KNO₃ may be added) 12) A.H. Holtzman & G.R. Cowan, Ordn 50,536, March-April 1966 (Explosive rivets were introduced in 1940 for fastening purposes particularly for the aircraft industry. Early expl rivets for aircraft were made of Al; more recently, high temp alloys such as Inconel X have been employed)

Note: Inconel X, Trademark of the International Nickel Co. Inc. for an age hardenable wrought alloy cons about 73% Ni, 15% Cr, 0.8% Al, 2.5% Ti and 0.85% columbium

Ref: CondChemDict (1961), 602-R

Explosive "Solox". Accdg to Dr. Herbert Ellem, private communication, Ferguson, Missouri, 30 Dec, 1972 it is a mixture of sulfur and aluminum

Explosive Screw. Buchanan designed & developed a 7/8 inch diam expl screw to meet the following requirements:

a) Must have an external contour in accordance with Drawing PX-8-380
b) Must withstand an acceleration of 5G’s
c) Must function satisfactorily at the end of 70 secs exposure to a temp change from ambient to 400°F
d) Must fail at any point on the 21/32 inch diam when assembled in a test fixture

The manufactured screws (600) met the prescribed requirements. The intended application of the Explosive Screw was classified Ref: E.H. Buchanan, PATR 1769 (1950) (Development of an explosive screw)

Explosive Seam Welding.

A unique, small-scale expl seam welding technique offers improvements over conventional expl welding. Expl welding, accomplished by colliding two metal plates explosively driven together, permits metallurgical bonding that is impossible to achieve by any other joining process, while maintaining material properties. The seam welding technique has successfully joined a variety of aluminum alloys and alloy combinations in thicknesses to 0.125 inch, as well as titanium in thicknesses to 0.056 inch. The explosively welded joints are less than one-half inch in width and apparently have no long-length limitation. The "ribbon explosive" developed in this study contains very small quantities of expl (RDX) encased in a flexible thin lead sheath and initiated with a blasting cap.

The evaluation and demonstration of this welding technique was accomplished in three phases: evaluation and optimization of ten major expl welding variables (plate material, plate thickness, explosive quantity: standoff, plate surface, plate deformation, mechanical shock, metal grain orientation, weld length, and expl residual), the development of four weld joints, and an applicational analysis which included photomicrographs, pressure integrity tests, vacuum effects, and fabrication of some potentially useful structures in aluminum and titanium.

This joining technique can complement existing fabrication techniques through its simplicity and the ability of producing low-cost joints with strengths up to that of the parent metal. A major disadvantage of this welding technique presently is the reservation in using expls. Other disadvantages are the destructive
mechanical shock produced by the welding operation, and sharp notches at joint interfaces creating stress concentrations. The author is continuing with this work and plans to apply the seam welding technique to a docking system for space stations. He is also interested in hearing of additional applications


**Explosives Sensitivity Data.** Card-gap and projectile impact sensitivity data are presented for a wide variety of explosive compositions tested at the Bureau of Mines in more or less standard test geometries. The results of both tests are in good agreement in that they provide the same sensitivity ordering for different subclasses of explosives. Least sensitive were homogeneous liquids that did not exhibit a tendency to undergo low-velocity detonation, Ammonium Nitrate-Fuel Oil, and most cast military explosives. Of intermediate sensitivity were pressed and powdered military explosives, cast Pentolite, permissible and non-permissible water-based explosives, and one commercial two-component explosive. The most sensitive were permissible and non-permissible Dynamites and explosives susceptible to low-velocity detonation


**Explosive Shattering.** See Explosive Disintegration


**Explosive Slurries.** Comps consisting of up to 20% water, much AN (dispersed and dissolved), possibly some NaNO₃, up to 35% of Al (from shavings down to 30µ in size), a high expl such as TNT, NS, or smokeless powder, perhaps a soluble organic fuel such as sugar, urea glycol, and frequently a natural gum thickener serve to make up expl slurries. An example in Ref 2 is AN 58, Al 32 & water 10%, with a density of 1.7 g/cc and an equivalence in 9 x 40-in size to 55% by weight more of TNT. The more water present the more necessary is a high expl to sensitize the slurry. High detonation pressure boosters such as Pento-lite or Tetryl are used as detonators


**Explosive Slurry Mixed On-Site in Canal Job.** A fluidized explosive, called Slurrex, was developed by Hercules Powder Co for widening the Panama Canal's three-mile Gaillard Cut from 300 to 500 feet. The work was supposed to be completed by Dec 1969. Accdg to manufacturer Slurrex enabled blast holes to be filled much faster than by conventional expls. It had also safety advantages, because no expl could take place until all ingredients of Slurrex are blended together and this takes place at blast site just before pumping into the blast holes. Slurrex used for underwater blasting is pumped into polyethylene bags, which resemble 3 to 4 feet sausages. Hercules Co said that precise energy control favors Slurrex's use in construction, open pit and strip mining
Explosive Starter. A device, used to start diesel engines, consists of a "cartridge-actuated device" (CAD), inserted in the head of one of the cylinders. On detonation of cartridge a shock (kick)s produced which pushes the piston down and starts the whole engine.

Note: CAD's are described in Vol 2 of Encycl., pp C70-R to C72-R

Refs: 1)R.A.Coffman, USP's 2299464, 2299465 & 2299466 (1942) 2)G.Cohn, Edit, Expls & Pyrots 3(1), 1970

Explosive Stimulus Transfer. Under a program to develop a technique to compute probability of detonation transfer between a donor and an acceptor, experiments were performed to measure the effects of seven variables. These included two donor parameters: fragment & slack energy; and five acceptor parameters: confinement, closure thickness, explosive material, explosive particle size and closure material.

The donor selected for this study consisted of detonating cord, ferrule & booster. The acceptor expl was confined in either a thin steel cup or a heavy-walled brass bushing. The experimental method consisted primarily of varying a single donor or acceptor parameter, and altering the air gap between the two until an approx 50% fire distance was obt

For the configurations tested, the following deton transfer principles were indicated:

a) variability in deton transfer is caused by differences in donor output; for a given acceptor design, sensitivity can be treated essentially as constant
b) detonation transfer could not be correlated with the pressure induced in an acceptor expl by donor fragments
c) large variation in extent of acceptor confinement did not appreciably affect deton transfer
d) for a single donor configuration at a fixed air gap, as the acceptor closure thickness was increased, it was necessary to increase acceptor sensitivity in order to maintain the same deton transfer probability

e) tests of two different particle sizes of the same expl showed the coarser material to be more sensitive to shock initiation, and the finer particle size more sensitive to fragment initiation
f) the pressure of any acceptor closure material had an adverse effect on deton transfer

The most significant parameter involved in deton transfer appeared to be the amount of energy induced in the acceptor expl by the donor. Small Scale Gap Test (See Vol 4 of Encycl., p D1085-R) results provided an indication of the amount of energy reqd to initiate an acceptor expl (Ref 1)

The effect on detonation transfer of the parameters shown in Fig Ex22 were reviewed for the donor and acceptor expls RDX, HNS-1 (2,4,6,2',4',6'-Hexanitrostilbene of 3 microns particle size) HNS-11 (Same as HNS-1, except of 200-300 microns particle size), DATB (1,3-Diamino-2,4,6-trinitrobenzene), and TATB (1,3,5-Triamino-2,4,6-trinitrobenzene) with a wide cross-section of sensitivities. Each of these parameters has been individually qualified and explained on both the theoretical level and the impact on practical hardware design. The experimental study is described in Ref 2 Refs: 1)M.L.Schimmel, "Quantitative Understanding of Explosive Stimulus Transfer (QUEST), McDonnell Douglas Corp Summary Report-Tasks 1 thru 6, MDC AID21, St.Louis, Missouri (June 1971) 2)L.J.Bement, "Quantitative Understanding of Explosive Stimulus Transfer", Mail Stop 498, NASA Langley Research Center, Hampton, Virginia, 23665 3)G.Cohn, Edit, Expls & Pyrots 5(5), 1972

Explosive Streamers. The design of continuous TNT charges for Mark 29 streamers, carried out at the Explosives Research Laboratory, Brierton, Pennsylvania, has led to the development of the Flexed TNT Charges. The method prep consists in filling reinforced rubber hose such as of 1 inch diameter
with molten TNT and subjecting the hose, while the TNT is cooling and solidifying, to a mild flexible operation. This produced an easily bending hose containing fine-grained TNT of density 1.4 g/cc which propagated detonation well and was insensitive to rifle bullet impact and to moisture (below 12%).

Six completed Mark 29 Explosive Streamliners, ranging in diameter from 1 to 2½ inches, were assembled at Yorktown Mine Depot and tested for propagation and damage by countermoving. Propagation trials were entirely satisfactory, but countermoving trials revealed damage to the outer 2½ inch hose of two streamers.

Explosive Streamliners are used for mine field clearance and for demolition projects. Ref: J.H. Lum & J.K. Bragg, ‘‘The Design of Explosive Streamliners’’ OSRD Rep. 1382 (1943), Pertinent to Navy Project NS-125, pp 146 & 378. (Compare with BANGALORE TORPEDOES; Detonating Cables; Demolition Hoses and Demolition Snakes, described in Vol 2 of Encyclopedia, pp B16-R to B18-L.

Explosive Strength. See under Explosive Properties.

Explosive Substances vs Thermites. According to Schimank et al., explosive substances are systems which are capable of exothermic chemical change, of a high reaction velocity, and which yield spontaneously gaseous end products wholly or in part.

Thermites are systems capable of exothermic chemical reactions, of great (or relatively great) reaction velocity, but not yielding any gaseous end products. Examples of Thermites: Al + Fe₂O₃, Al + KClO₃, etc. Refs: 1) H. Schimank, Zelektrochem 24, 213-14 (1919) 2) W. Bieger & H. Schimank, ibid, 24, 354-56 (1919) & CA 14, 347 (1920) 3) A. Langhans, SS 13, 310-13 (1918) & CA 14, 842 (1920)

Explosive Switch. An electric switch operated by an electric squib or primer, such as the MK66 MOD 0. This switch is manufactured by the Atlas Powder Co. The dimensions of the switch housing are ½ x ½ x 2-1/8 inches. It is a single pole quadrupole throw switch containing four circuits, two open and two closed. The bridge lead wires extend from one end of the switch a minimum of 4 inches. The bridge wire is nichrome and is approx. .001 inch in dia. Its resistance is 1.8 ± 0.2 ohms. The ignition spot and base charge consists of LMNR and KClO₃ (95-5). The base charge is loaded in two increments, 30 mg at 5000 psi and 25 mg loose.

The pressure, exerted against the piston by activation of the squib, overcomes the flange on the piston and drives piston forward which causes the switch slider to move. After traveling a given distance, the slider is locked in place. The locking action takes place when the end contactor in the slider springs into a notch cut into the contact pin holder.

Fig Ex 23 is the switch MK66 MOD 0. (Ref 1). There is also given Fig Ex 24 of the Switch MK 46 MOD 0 and Fig Ex 25 of its Actuator MK 3 MOD 0.

The most recent Army explosive switches consist of the XM60 series (Ref 3). All have six pairs of contacts and measure 3/8 by 3/8 inch. The non-delay switches are 2 inches long while the delay switches are 2½ inches long, the extra length being needed to accommodate the delay column in the squib. The squib charges are similar to those in the MK 66 Mod 0 and the switches look the same except, of course, that there are six contact pairs instead of four. Contacts are double-pole and single-throw with various combinations of normally open and normally closed contacts to permit versatility. The following table lists the available switches while the diagram illustrates a typical contact arrangement.
Explosive Switches of XM 60 Series

<table>
<thead>
<tr>
<th>XM No</th>
<th>Delay</th>
<th>Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>None</td>
<td>6 0</td>
</tr>
<tr>
<td>61</td>
<td>&quot;</td>
<td>2 4</td>
</tr>
<tr>
<td>62</td>
<td>&quot;</td>
<td>3 3</td>
</tr>
<tr>
<td>63</td>
<td>&quot;</td>
<td>5 1</td>
</tr>
<tr>
<td>64</td>
<td>100 MilliSec</td>
<td>2 4</td>
</tr>
<tr>
<td>65</td>
<td>1 Sec</td>
<td>3 3</td>
</tr>
<tr>
<td>66</td>
<td>2 Sec</td>
<td>3 3</td>
</tr>
<tr>
<td>67</td>
<td>2 Sec</td>
<td>4 2</td>
</tr>
<tr>
<td>68</td>
<td>100 MilliSec</td>
<td>4 2</td>
</tr>
</tbody>
</table>


Contact Arrangement of XM 61 Switch
FIG Ex24. EXPLOSIVE SWITCH
MK 46 MOD 0

FIG Ex25. EXPLOSIVE ACTUATOR
MK 3 MOD 0
Explosive Systems, Liquid; Sensitivity Characteristics of. The card gap method was used to determine the sensitivity of the following high-energy liquid explosive systems:

a) Hydrogen Peroxide-Glycerin
b) 50/50 Nitroglycerin-Ethylene glycol Dinitrate
c) Nitroglycerin-Ethylene glycol Dinitrate-Triaocetin

Further improvements were made to follow continuously the initiation & growth of high velocity detonation, low velocity detonation, and low velocity reaction. Shock sensitivity scales were established in Al, Plexiglas & polyethylene container. Also several other casting solvents were compared with the above liquid expls.


Explosive Train. See Vol 4, pp D836-R to D839-L and Figs 1-21a and 1-21b and the following Refs


Explosive Train Test. See Ref 81 in Vol 4, pp D345-L & D345-R. It is an abstract of description given in TM 9-1300-214/T0-11A-1-34 (1967), under the title "Initiating Value Test"

Explosive Test. A normally closed valve opens 3 milliseconds after application of an electrical pulse to a high-temp propellant cartridge. In this one-shot device input from a high pressure line meets a diaphragm, which is too weak to hold off line pressure on its own. Support is provided the opposite face of the diaphragm in the form of a hollow piston, held in place by a shear ring. Upon firing of the propellant, the piston shears the ring and moves the support from the diaphragm. It removes the fluid to flow thru the cylinder to a delivery line. The device is capable of operating at fluid pressures of 6500 psig, at temps -65 to 235°F and at altitudes to 200000 feet

Refs: 1) McCormick Selph, PO Box 6, Hollister, Calif, 95023 2) G. Cohn, Editor, Expls & Pyrots 1 (4), 1968 (Abstract)

Explosive Testing in Europe, Standardization of. The 5th Meeting of the European Commission for Standardization Tests of Explosives was held at Dormund-Derne, Germany on 20-23 October 1971. Forty-two experts from 12 countries attended. Topics discussed included: Lead Block Tests (describing influence of lead quality on test results and manuf of Trazul Block), Aluminum Block Tests, Detonator Strength Tests, Detonation Through Plastic Disks, Detonation Transfer, and Graded-Strength Blasting Caps for Test Purposes


Explosive Wave Shaping by Delayed Detonation was discussed by the late M.M.Sultanoff at the Proceedings of the First Symposium on Detonation Wave Shaping (sponsored by Picatinny Arsenal) at the Jet Propulsion Laboratory, Pasadena, Calif, June 5-7, 1956

Explosive Welding. Accdg to Philipchuk (Ref 1), Davenport & Duval (Ref 2) lap-type welds of various metals by explosive force have shown experimentally to be entirely feasible. However at the present, it does not appear to be a process which will replace normal welding techniques where a simple weld is adequate and the cost must be kept low. However, it may be used advantageously in the welding of high temperature or refractory metals, metals that are degraded by heat, where large area welds are desirable or where normal welding equipment is difficult to use (See Fig Ex 26)
Acording to Addison et al (Ref 3), expl welding can join many similar and dissimilar material combinations, some of which are often difficult, if not impossible, to weld by the fusion welding processes. With expl process, welding occurs when adjacent surfaces of materials to be joined are properly positioned and thrust together by energy released from an expl source. No external heating is normally introduced in the welding operation, although some heat is generated at the weld interface because of the absorption of energy. Applications of expln welding include: cladding of tubes for reactors; lining of half cylinders for turbine engine applications; cladding of cylinder bores and pistons; welding of pipes and tubing of dissimilar materials for aerospace, cryogenic, and reactor applications; cladding of pressure and mixing vessels for the chemical and petroleum industries, etc. Increasing attention is being given to the welding of tubes to tubeplates for heat exchanger applications.

Etzel & Munford (Ref 4) describe an electromechanical device that automatically measures and displays the embedment of each welded joint and locks out the welding machine if the embedment value is not within present upper and lower limits.

Lindb & Pershak (Ref 5) describe a semi-empirical method for predicting the effect of weld defects on static and fatigue properties.
of weldments and investigated the effects of repair welds on weldments.

Pattern (Ref 6) developed a method for producing permanent tube joints that exhibit decreasing leak rate with increasing service temperature.


EXPLSIVES are solid, liquid and gaseous substances possessing the property, when subjected to either heat, impact, friction or other initial impulse, of undergoing a very rapid exothermic self propagating transformation or decomposition with the formation of more stable materials (usually gases), accompanied by the production of a very loud noise (report) and the development of very great pressures and very high temperatures. This action is called explosion or detonation.

The products of exps or compounds containing sufficient oxygen for complete combustion (such as NG) are exclusively gaseous (CO₂ and H₂O); for those containing insufficient oxygen (such as TNT) the gaseous products (CO₂, CO, H₂, CH₄, H₂O etc) may be mixed with some solid particles of carbon (smoke). Still other exps such as Lead Azide, Copper Azide, Silver Fulminate etc, produce some metallic particles in addition to gases. In a few cases, such as with Copper Acetylide, no gases are developed whatever, only solid particles of C and Cu; it seems that any expl value of such materials depends on the heating effect on adjacent gases. The gaseous products of exps generally have a volume much greater than that of the expl itself. The work done by an expl is determined primarily by the amount of heat given off during the exps. An important characteristic of nearly all exps (except Initiating Compounds) is their oxygen balance (See under Available Oxygen in Vol 1, p 515). Solid and liquid exps can be divided into two classes:

A) Low Explosives (LE) or Propellants and
B) High Explosives (HE)

A) Low Explosives, such as Black Powder or Smokeless Propellant when used as propulsive charges, undergo deflagration (rapid burning) at rates ranging from centimeters to meters per second. This is accompanied by the development of large volumes of gases, high temperatures and pressures, but no real exps take place - the gases simply push the projectile out of the weapon (propulsive action). They also can be used as commercial Blasting Explosives.

B) High Explosives are those which undergo detonation, or explosion in a small fraction of a second.

High Explosives (HE) can be divided into HE proper and Initiating Explosives. In our opinion, this classification is inadequate because it overlooks a class of expls (such as commercial Blasting Powders) which cannot strictly be called HE because they are of comparatively low brisance and velocity of detonation. They possess "heaving action" and are not suitable as bursting charges in projectiles or for blasting operations in hard rock. For this reason we would like to propose the following subdivision of HE's:
1) Priming (or Primary) Explosive Compounds or Mixtures (such as Lead Dinitroresorcinate and Lead Styphnate) are sufficiently sensitive to impact or friction to explode (or deflagrate), developing a high temperature and producing a flame, but not a real detonation. They are used as priming (top) charges in compound detonators.

2) Initiating (or Detonating) Explosives are sufficiently sensitive to heat, impact or friction to undergo detonation and to transmit the detonation wave to less sensitive expls as described below. As a rule these expls are less brisant and less powerful than HE, but there are some exceptions, notably Cyanuric Triazide. Merccuric Fulminate (MF) had been used until recently in single component detonators but now it is nearly completely replaced by Lead Azide (LA) which is used as base (detonating) charge in compound detonators. As their top charge Lead Styphnate (LS6) is used (See DETONATORS, IGNITERS AND PRIMERS in Vol 4, pp D733-L to D743-R).

3) High Explosives differ from primary and initiating expls in not being exploded as easily by impact, friction or heat. They may be divided into the following subgroups:

a) Highly Brisant and Sensitive HE’s such as Blasting Gelatin and 60% Gelatin Dynamite, possess high brisance and power, but are too sensitive to be used for military purposes as boosters or bursting charges in shells. They can, however, be used as demolition charges or for blasting hard rocks. Their detonation velocities can be approx 7500 to 8500 m/sec.

b) Booster Type HE’s: such as straight Terryl, PETN or RDX are very brisant and powerful expls, less sensitive to mechanical shock than a, but too sensitive to be used as bursting charges in shells but suitable as booster charges. Their detonation velocities can be approx 7000 to 8000 m/sec.

c) Bursting Type HE’s such as TNT, Pentolite, Composition B or Tetryl are brisant and powerful, and are sufficiently insensitive to shock to be used as bursting charges in shells. They are very difficult to detonate directly by detonators or blasting caps (unless they are very large ones) and for this reason boosters are used as intermediate charges in order to insure complete detonation. The detonation velocity of bursting type HE’s are approx 7000 m/sec. Cannot be used for blasting soft coal or ground but can be used for blasting hard rock.

d) Commercial Blasting Explosives, such as Low and Dynamites (not higher than 40%), Permissible Explosives and Black Powder (when used as an expl and not as a propellant), are fairly powerful but of very low brisance and velocity of detonation (such as 300 to 3000 m/sec). Their action is propulsive (heaving) caused by hot gases which are evolved on expln. They are used for blasting soft rock, the ground, or coal, but cannot be used successfully in modern shells because most of their energy would be dissipated in rupturing the walls of the shells and their fragments would be too big and too few. Blasting expls are usually less expensive than military expls and this is the important reason for their commercial use.


EXPLOSIVES (LISTED IN PREVIOUS VOLUMES OF ENCYCLOPEDIA).

As a rule explosives were listed and described under their parent compounds arranged in alphabetical order, as for example 2, 4, 6-Trinitrotoluene or Picramide is described under ANILINE in Vol 1 of Encycl. Most of the metallic salts are described under the names of their anions as, for example, Lead Azide (LA) is described under AZIDES, Merccuric Fulminate (MF), under FULMINATES, whereas some salts are described under the names of their cations, as for example Ammonium Nitrate (AN) is described under AMMONIUM in Vol 1.

As an exception there are listed in several volumes, explosives, not completely descr-
scribed but with listed important explosive properties, such as shown in the following examples;
1) Vol 2, p B29 - Belgian Industrial Explosives
2) Vol 2, pp B202-R to B203-R - Blasting Explosives
3) Vol 2, p B211-R - Blasting Gelatin
4) Vol 2, pp B266 to B297 in Table 1, under BRISANCE are listed about 340 explosives with their Brisance and Power, whereas in Table II on p B298 are listed Detonation Velocities of 21 explosives
5) Vol 2, Tables 1 to 6, pp C156 to C159 are listed CHEDDITIS
6) Vol 3, under COMMERCIAL EXPLOSIVES are listed on pp C437-L to C444-R "Coal Mining Explosives, Nonpermissible", while on pp C444-R to C456-R are "Coal Mining Explosives Permissible"
7) Vol 5, pp D1584-L to D1742-R are described DYNAMITES

EXPLOSIVES (BOOKS AND PAMPHLETS
Listed in Chronological order)
3) J.Daniel, "Dictionnaire des Matières Explosives", Dunod, Paris (1902)
4) A. Noble, "Artillery and Explosives", Murray, London (1906)
5) L. Gody, "Traité Théorique et Pratique des Matières Explosives", Wesmäel-Charlier, Namur (1907) 5a) R.Escales, "Die Explosivstoffe", Veit & Co, Leipzig (1908-1926), which includes: I.Schwarzpulver und Sprengsalpeter; II. Die Schiessbaumwolle; III. Nitroglycerin und Dynamit; IV.Ammonsalpersprengstoffe; V. Chloratsprengstoffe; VI. Nitrothromstoffe; VII. Initialexplostoffe; VIII. Das rauchlose Pulver
6) P. Chalon, Les Explosifs Modernes, "Ch. Béranger, Paris (1911)
7) G.W. MacDonald, "Historical Papers on Modern Explosives", Whittaker, London & NY (1912)
8) W.R. Quinan, "High Explosives", Crichtley-Parker, London (1912)
12) E. de W.S. Colver, "High Explosives", Van Nostrand, NY (1918)
13) E. de B. Barnett, "Explosives", Van Nostrand NY (1919)
14) P. Verola, "Chimic et Fabrication des Explosifs", A. Colin, Paris (1920)
16) H. Kast, "Spreng- und Zündstoffe", Vieweg, Braunschweig (1921)
19) Ph. Nauém, "Nitroglycerine and Nitroglycerine Explosives", translated from Ger by E.M. Symmes, Williams & Wilkins, Baltimore (1928)
20) R. Molina, "Explosivi e Modo de Fabricarli", Hoepli, Milano (1930)
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23) A. Steibach, "Die Schiess- und Sprengstoffe", Barth, Leipzig (1933)
24) J. Reilly, "Explosives, Matches and Fireworks", Van Nostrand, NY (1938)
25) K.K. Smitko & M.A. Budnikov, "Vzryvchatyiye Veshchestva", Artilleriiskaya Akademia, Moscow (1939)
25a) E. Piantanida, "Chimica degli Esplosivi e dei Gas di Guerra", Tipo-Litografia della Accademia Navale, Livorno (1940)
26) A.G. Gorst, "Khimiya i Tekhnologia Nitrosyiedinenii" (Chemistry and Technology of Nitrocompounds), Oborongiz, Moscow (1940)
26a) "Thorpe's Dictionary of Applied Chemistry", Vol 4 (1940)
27) E.E. Sancho, "Quimica de los Explosivos", Aguado, Madrid (1941)
27a) V. Mathesius, "Zur Geschichte der Sprengstoffe", Hoppenstedt, Berlin (1941) [Reviewed in SS 37, 111-12 (1942)]
30) M. Meyer, "Explosives", Crowell, NY (1943)
33) H. Kast & L. Metz, "Chemische Untersuchung der Spreng- und Zündstoffe", Vieweg, Braunschweig (1944)
34) H. Blatt et al, "Compilation of Data on Organic Explosives", OSRD Rept 2014 (1944)
36) A. Pérez Ara, "Tratado de Explosivos", Editorial Cultural, La Habana (Cuba) (1945)
36a) "The Preparation and Testing of Explosives", Summary Tech Rept of Div 8, NDRC, Vol 1 (1946)
37) N.A. Shilling, "Vzryvchatyiye Veshchestva i Naruzheniye Borepriparatov" (Explosives and Ammunition Loading), Oborongiz (Moscow) (1946)
39) A. Mangoni, "Quaderni di Chimica Industriale No 14, Esplosivi", Pàtron, Bologna (1947)
40) A. Sterttbacher, "Spreng- und Schießstoffe", Rascher, Zürich (1948)
42) M. Giua & C. Giua - Lollini, "Dizionario Li Chimica Generale e Industriale", UTET, Torino, Vols 1-3 (1948-1950)
43) T. Thalalsden, "Ekspluvistsoffter", Dreyers Verlag, Oslo (1950)
45) C. Belgrano, "Gli Esplosivi", Hoepli, Milano (1952)
46) A. Sterttbacher, "Pólvoras y Explosivos", G. Gili, Buenos Aires (Argentina) (1952)
48) B. Wiesner, "Der Verkehr mit Sprengstoffen" (Intercourse with Explosives), E. Barth, Mannheim (1952)
49) F. Weichelt, "Handbuch der gewerblichen Sprengtechnik", C. Marhold, Halle (1953)
50) H. Gilman, Editor, "Organic Chemistry", Vol 4 (1953), Chapter on Chemistry of Explosives, pp 952-1000 by G.F. Wright
51) L.V. Dubnov, "Predokhanitel'nyiiye Vzryvchatyiye Veshchestva" (Permissible Explosive Substances), Oborongiz, Moscow (1953)
52) D. Smolenski, "Teoria Materialów Wybuchowych" (Theory of Explosive Substances), Wyd Ministr Obrony Narodowej, Warsaw (1954)
57a) B.T. Fedoroff et al, "Dictionary of Russian Ammunition and Weapons", PATR 2145 (1955)
58) Anon, Military Explosives; TM-9-1919 (1955)(See its Revision Ref 89)
59) M.A. Budnikov, A.A. Levkovich & I.V. Bystrouk, "Vzryvchatiye Veshchestva y Porokha" (Explosive Substances and Propellants), Oborongiz, Moscow (1955)
60) A.G. Gorst, "Porokha y Vzryvchatiye Veshchestva" (Propellants and Explosives), Oborongiz, Moscow (1955)
61) N.E. Yaremenko & B.Ya.Svetlov, "Teoriya i Teknologiya Promyshlennykh VV" (Theory and Technology of Industrial Explosives), Promstroyizdat, Moscow (1957)
63a) R. McAdam & R. Westwater, "Mining Explosives", Oliver & Boyd, Edinburgh (1958)
64) B.T. Fedoroff et al, "Dictionary of Explosives, Ammunition and Weapons" (German Section), PATR 2510 (1958)
65) W.R. Tomlinson, Jr & O.E. Sheffield, "Properties of Explosives of Military Interest", PATR 1740, Revision 1 (1958)(See also Ref 88)
67) T. Urban'ski, "Chemia i Technologie Výbusín" (Chemistry and Technology of Explosives), Státní Nakladatelství Techniké Literatury, Praha, Vol 1 (1958)
69) W. Taylor, "Modern Explosives", Royal Institute of Chemistry, Monograph No 5, London WC1 (1959)
71) Anon, "Analytical Methods for Powders and Explosives", AB Bofors Nobelkrut, Sweden (1960)
71a) C.E. Gregory, "Explosives for Engineers" A Primer for Australian Industrial Practice, Univ of Queensland Press, Brisbane (1960)
77a) K.K. Andrejev et al, "Teoriya VV" (Theory of Explosives), Oborongiz, Moscow (1963)
78) V.A. Assonov, "Vzryvchatiye Veshchestva v IIkh Primeneniyu v Gornoy Promyshlennosti" (Explosives and Their Use in Mining Industry), GosNauchTehkhnizdat, Moscow (1963)
80] E.L. Gómez, "Estudio de los Explosivos Industriales", Madrid, reviewed in Explosivstoffe 1964, 126
81] M. Novotný & V. Pesata, "Teorie Prumyslových Traskavy" (Theory of Industrial Explosives), StatiNaklTechLit, Praha (1963)
82a] A.A. Shidlovskii, "Osnovy Pirotekniki" (Fundamentals of Pyrotechnics), Oboronhiz, Moscow (1964) [Engl translation by US Joint Publications Research Service, PATM 1965 (1965)]
87] E.I. duPont de Nemours, "Blasters' Handbook", Wilmington, Delaware (1966), pp 25-8 (Black Powder); 29-46 (Dynamites); 47-68 (Blasting Agents); 68-80 (Water Gel Explosives); 81-86 (Jet Tappers); 87-110 (Initiating Devices)
91] F.A. Baum et al, "Termoystykiye VV i Ikh Deystviye v Glubokikh Skvazinakh" (Thermally Stable Explosives and Their Action in Deep Boreholes), Nedra, Moscow (1969)
95] A.G. Gost, "Porokha i Vzryvovye Veshchestva" (Propellants and Explosive Substances), Izdat "Mashinostroeniye", Moscow (1972)

The following complimentary copies were received from Dr O. Vettori of Aulla (Massa C), Italy:
A) Pamphlet: "Sorlini Esplosivi SPA", Brescia, N. Italy
B) Pamphlet: "Esplosivi Mangiarotti", Codroipo(Udine)(1959)
C) Book: C. Giorgio, "Tecnica degli Esplosivi", DelBianco-Udine (1964)
D) Book: E. Brandimarte(Accademia Navale, "Le Cariche di Scoppio" (Bursting Charges), Poligrafico dell'Accademia Navale, Livorno, Italy (1966)
E) M. Busco, "Optica Geometrica degli Esplosivi", Vol 1 (Geometric Optics of Explosives), Published by Author, Vile Quatro Venti, 247-Roma (1973)
F) M. Busco, "Optica Fisica degli Esplosivi" (Physical Optics of Explosives), Roma (1973)
EXPLOSIVES OF MILITARY INTEREST
(Papers and Reports Listed in Chronological Order)

In addition to references listed under individual explosives in Vols 1, 2, 3, 4 and 5, the following may be included:
1) J.D. Hopper, "Study of Fundamental Properties of High Explosives". PATR 838 (1937)
2) E. von Herz & Ph. Naouim, GerP 659721 (1938) (A moldable methylxanamide and nitrocompds used for making charges such as with TNT, TNNaphthalene, etc)
3) G.C. Hale, USP 2202851 (1940) & CA 34, 6815 (1940) (Explosive suitable for bombs and shells, such as consisting of PA 85-90 & MNaphthalene 15-10%)
4) J.D. Hopper, PATR 1041 (1940); 1063 (1940) and 1133 (1941) (Explosives of High Brisance)
5) D.D. Sager, PATR 1155 (1942) (Explosives of High Brisance)
6) W.R. Tomlinson, Jr, PATR 1170 (1942) (Explosives of High Brisance)
7) R.H. Kent, "Explosives and Their Military Application", JAppiPhys 13, 348-54 (1942) (Definition is given of terms: Sensitiveness to Impact & Friction (p 348), Force (p 349), Rate of Detonation (p 350), Density (p 351), Pressure (p 352), Energy (p 352), Blasting Power (p 352), Brisance or Shattering Power (p 352), and Phenomena Attending an Explosive (pp 353-54)
8) A. Stettbacher, Protar 8, 81-92 (1942) & CA 37, 1603 (1943) (Theoretical discussion based upon the following values: density (d), gas vol per kg of expl (Vg), heat of explosion (Q), temp of explosion (T) and the sensitiveness to impact (S). The opinion is expressed that explosive technique cannot find anything new because all possibilities have been explored, and further advance must consist in finding new methods of use)
9) Schweiz Sprengstoff-Fabrik AG, SwissP 226852 (1943) & CA 43, 2438 (1949) (Highly brisant expl of low sensitivity to shock consists of PETN desensitized by a mixture of paraffin and nitropentaerythritol in which at least 3 OH groups are esterified with stearic acid)
10) W.R. Tomlinson Jr, PATR 1360 (1943); 1379 (1944); 1402 (1944); 1414 (1944); 1429 (1944); 1437 (1944) and 1452 (1944) (Explosives, Ternary Mixtures)
12) H.A. Aaronson, PATR 1469 (1944) (Properties of Ternary Mixtures of High Explosives)
13) Wm. H. Bagley Jr, USP 2369517 (1945) & CA 39, 3162 (1945) (Explosive suitable for small-caliber projectile comprises a highly electropositive material such as Pb₈(OH)₄(CIO₄)₂ 84% and a highly electronegative material such as powdered Al 16%, both of 200-400 mesh granulation. The mix is compressed to about 1/3 its vol. An alloy of Al and Ca, or straight Mg may be substituted for the Al, and Ca₈(OH)₄(CIO₄)₂ for the basic Pb salt)
14) H.L. Porter, CIOs 33-27, pp 6-46 (1945-1946) (Explosives, Hollow Charge and Shock Waves) [Description of work at the Physics and Ballistics Institute, Air Ministry, Berlin, under Director Dr H. Schardin is given. It was claimed that Dr Max von Förster had shown in 1883 (earlier than Ch.E. Monroe) that bare hollow charges gave an enhanced effect along the axis of the charge]

The following persons, besides Schardin, worked at the Institute on hollow (shaped) charges:

Dr C. Cranz, who published, in collaboration with Dr H. Schardin, the paper in ZPhys 56, 147 (1929) (See pp 6-27 of Porter's)
Prof W. Döring (See pp 28-32 of Porter's)
Prof R. Becker (See pp 36-38 of Porter's)
Prof W. Fuchs, in collaboration with Dr H. Schardin (pp 40-42 of Porter's)
15) L.H. Eriksen, PATR 1506 (1945) (Properties of Ternary Mixtures of High Explosives (Exudation Study of PTX-1))
15a) L.H. Eriksen, PATR 1623 (1946) (Properties of Ternary Mixtures of High Explosives. Effect of Storage on Ternary High Explosives)
16) J. Taylor & S.H. Davidson, USP 2395353 (1946) & CA 40, 3606 (1946) (A TNT expl of d 1.55-1.60 which may be press-loaded is prep'd in an Atlas mixer - a jelly of 17 parts NG and 1 p NC with 1 p kieselguhr, 1 ρ β-naphthyl methyl ether and 80 parts of pulverized TNT. The mixture had to be loaded at once because it sets on standing to a solid mass)

17) W.W. Vogl, USP 2406572 and 2406573 (1946) & CA 41, 286 (1947) (Explosives suitable for loading shells, boosters, etc conts Ethylendiamine Diperchlorate with other ingredients, such as TNT; also an addn compd of Ethylendiamine Perchlorate with PA, etc)

18) V.H. Williams & H.R. Wright, USP 2407595 (1946) & CA 41, 286 (1947) (Powerful detonating expls composed of crystal polyanitric esters (such as PETN or HN-Mannitol), a nitroaromatic compd liquid at RT and NC with N content >11.8%)

19) H.R. Wright & J. Taylor, USP 2407597 (1946) & CA 41, 286 (1947) (Powerful expl of low sensitivity to impact or friction composed of a mixt of liq Nitrotoluences, TNT, Tetryl, NC, inorganic nitrates and metal powders)

20) J. Taylor et al, BritP's 578370 & 578371 (1946); CA 41, 1842 (1947) (Incorporation of highly absorbent kieselguhr (5 to 7.5%) into molten TNT produces a cast charge with higher deton velocity than that of cast TNT alone. Other ingredients, such as NG with sol NC may be added. E.g. mixture of TNT 70-85%, kieselguhr 5%, NG 15-20%, sol NC up to 7.5 % & stabilizer 5% had density ca 1.6, deton vel up to 6500m/sec and could be initiated by No 6 detonator)

21) H.H. Fassnacht & C.A. Woodbury, USP 2425310 (1947) & CA 41, 6724 (1947) (A HE suitable for military and industrial purposes consists of Tetryl 7-90, a liquid aliphatic nitric ester, or an aromatic nitrocomp 5-85 and NC 0.1-7.1%. It is insensitive to rifle bullet impact and possesses high velocity of detonation even after prolonged storage)

22) R.W. Cairns, USP 2430274 (1947) & CA 42, 764 (1948) (An explosive suitable for cast loading was prep'd by blending 8.5 parts of NS salt moistened with 1.5p alcohol with 10p of pulverized TNT. After drying at RT the mixt is heated at 80-95° to obtain a homogeneous viscous liquid and then poured into molds or shells)

23) V.L. Bobolev, DoklAkadNauk 57, 789-92 (1947) & CA 46, 4797 (1952) (Limiting diameters of charges of chemically uniform explosives)


26) G.C. Hale, USP 2472105 (1949) & CA 43, 6827 (1949) (Explosives more powerful than TNT and suitable for cast-loading shells, bombs, etc consist of EDNA (Ethylene-dinitramine)<60 and TNT >40%)

27) L.F. Audrecht & D.D. Sager, USP 2482089, 2482090 and 2482091 (1949); CA 44, 840 (1950) (Three-component expls, such as TNT, Tetryl & RDX; TNT, EDNA & Tetryl or TNT, EDNA & PETN are of high density and are more powerful than TNT. They are suitable for loading, preferably by casting of shells, bombs and mines)


28) F.M. Lang, MP 35, 213-22 (1953) (Solubilities of explosives in several solvents) Translated by N. Gelber, FREL, PicArsn, Translation No 52, Sept 1959

29) A. Schmid, Explosivstoffe 1954, pp 121-24, "Die Konstitution reinen explosiven Verbindungen"


31) K. Yamasue et al, JapP 2097 (1954) & CA 49, 2076 (1955) (Expls mixts of nitratd naphthalene and toluene with NC, NG, etc)
31a) B.T. Fedoroff et al., "Dictionary of Russian Ammunition and Weapons", PATR 2145 (1955) (Includes explosives and propellants used by the Russians during WWI and WWII) (Varityped)
33) W.S. Cramer, "Bulk Compressibility Data on Several High Explosives", NOLRept NavOrd 4380 (1956)
34) B.J. Zlowucha & M. Baer, PATR 2288 (1956) (Reactivity of explosives with metals and protective finishes)
35) M.A. Cook et al, JACS 79, 32 (1957) (Velocity-diameter curves, velocity transients and reaction rates in PETN, RDX, EDNA & Tetryl)
37) C.G. Dunkle, "Detonation Phenomena", Picatinny Arsenal-Stevens Graduate School Program, Twenty-six Syllabi (1957-1958), Metallized Explosives, p 274
38) P.B. Tweed, FREL, EDS Rept No 23, March 1958 (The Significance of Explosives in Threads)
38a) B.T. Fedoroff et al, "Dictionary of Explosives, Ammunition and Weapons" (German Section), PATR 2510 (1956) (Varityped 345 double column pages)
39) Poudreries Réunies de Belgique, Rept LC No 186, October 1958 (Preparation of certain castable explosives based on TNT)
41) E. Piantanida & M. Piazzii, Chim e Ind (Milano) 43, 1389-93 (1961), Engl translation as PATM (PicArsnTechMemorandum) (1962) (Behavior of Explosives Under the Action of Gamma Rays) [Exposure of PA (Picric Acid) and TNT, representatives of the aromatic nitrates, to doses as high as 20 megaoentgens for 660 hours did not show any significant decrease in stability as shown by the Taliani Test at 120°C and lowering of the mp. PETN, representative of the nitrate explosives, was reduced rapidly in chemical stability by as much as 0.5 mgroentgens. Nitramine explosives, exemplified by RDX, while not showing the extremely high resis-
tance to gamma radiation as that of the nitro-
arenes, resisted satisfactorily 20 mega-
roentgens. Long exposures to low intensities, 10 roentgens per min for 70 days, cumulative
dose of 1 megaroentgen, had very little
effect upon the explosives except PETN.
However, the effect was very small. 
Extremely small intensities for very brief periods, 
(10y for 0.3 min; 10000y for 20 min), followed 
by long aging, showed the radiation had no 
effect upon the stability of the expls]
42) W. Sh. Dutton, "One Thousand Years of 
Explosives, From Wildfire to the H-Bomb", 
Winston, Philadelphia (1960)
43) F. Spring & Ch. Glauser, GerP 1078918 
(1960) & CA 55, 17007 (1961) (Desensitized 
RDX explosive was prep by kneading a mixt 
of 69g RDX & 29g Al powder (of 100μ particle 
size) with 16g of lacquer added by portions. 
The lacquer consisted of Et cellulose 7.7, 
di-Bu phthalate 3.3, Centralite 1.3 and various 
organic hydrocarbons 87.7%. Then the mixt 
was rubbed thru a screen, dried and sieved 
to obtain 0.5-2.0mm particles]
44) W.A. Gey, USP 2982639 (1961) & CA 55, 
17008 (1961) [Non-sticky expl compn having 
low shock sensitivity and high density is 
obtained by incorporation into HE (such as RDX) 
ca 10% of an ether of linear Methylenenitro-
amines or mixts thereof having the general 
structure RCH2IN(NO2)2CH2xR, where R is 
H, alkyl or alkoxy; R' is alkoxy and x is an 
integer. A detailed description of prepn of expl 
compn consisting of RDX, Di-n-amyl 
ether of ATX (1,7-Dinitroxy-2,4,6-trinitro-
2,4,6-triazaheptane) and "Span" is given]
45) Th.G. Blake, USP 2982640 (1961) & CA 55, 
17007 (1961) (Deflagrating exps for 
loading 20-mm and 40-mm projectiles is pro-
vided by a mixt contg 30-70% of finely 
divided metal (such as Al, Mg, Zn, Zr, Ti, B 
or alloys), 18-35% of an oxidizer (such as a 
nitrate or perchlorate of Amm, alkali-
or alk-earth metals); 2-4% of TNT (coated on an 
oxidizer) and 6-30% RDX. Incorporation of 
2 parts Cu stearate and 1 p graphite aided in 
pelleting]
46) J.W. Dawson & F.H. Wesheime, USP 
2982641 (1961) & CA 55, 17008 (1961) (Alumized
expls with greatly reduced or eliminated spewing and gas-generating tendencies were obtd by incorporating a hydrolphile or desiccating agent, such as Mg(NO₃)₂, CaCl₂, or Mg(ClO₄)₂. This compn contg Al (fine) 18, RDX 42 & TNT 40%, with added 0.5% of fine anhyd CaCl₂ had a sharply reduced tendency to spew and generate gas both while pouring and after introduction into containers.


54) M.F. Murphy, "Two Explosives Generating Condensible Products", NOLTR 63–12 (1963) [Mixts studied were Lithium Perchlorate Trihydrate (3 moles) & Aluminum (8 moles) and amorphous Al powd with aq hydrogen peroxide (90%)].


56) Anon, Ordn 51, 94 (July–Aug 1966) [New expls Astrolites have been produced by the Explosives Corp of America, a subsidiary of Rocket Research Corp. It is claimed that some of these expls are more powerful than Blasting Gelatin. Their comps are not given but it is evident that they are different from those of Astralites, described in Vol 1 of Encycl, pp A497–R & A498–L and in PATR 2510 (1958), p Ger 10. See Ref 63a].

57) PATR 2700, Vol 3 (1966), pp D38–R to D40–L (Deflagrating expls; definition).

58) PATR 2700, Vol 3 (1966), p D107 (Detonating expls; definition).


63) Anon, "Explosives and Demolitions", FM 5–25 (1967), p 155–R (Sheet explosive M118 for use in military demolition block, weighing 0.90 kg. No compn given but its deton velocity is 7190m/sec).


Reviewed by G. Cohn, Edit in Expls&Pyrts 6(4), 1973. (This compilation records compatibility testing at Picatinny Arsenal. Compatibility indicator was the result of gas evolution determined in the vacuum stability test. Reports present the information in two ways: by generic name or trade name of the plastic and by explosive. The reader can quickly scan the information to see with what expls a plastic is compatible and what plastics can be used safely with a particular explosive.

65) Bruce Anderson, Ordn 53, 613-15 (1969) [The values of so-called Figure of Merit (gas volume times heat of explosion) are given for Astrolite A-1-5 as 1600, while for Astrole G as 1175, in comparison with TNT 675, Tritonal 792 & RDX 1162.

No compns of Astrolites are given.] 66) PATR 2700, Vol 4 (1969), pp D574-R & D575-L (1969) (States properties of explosives) 67) Anon, Atlas/Aerospace No 8, 1969, Atlas Chemical Ind, Valley Forge, Pa 19481; reviewed by G. Cohn, Edit in Expls&Pyrts 3(3), 1970 under the title Explosives for Actuators [LMNR (Lead Mononitroresorcinate), KDNBF (Potassium Dinitrobenzofuroxane) and BaSt (Barium Styphnate) are the three common materials used as either ignition drops or base charges in actuators, motors, switches, and matches. LMNR, a stable, low-cost comp, is always used with 5 to 40% KCIO3. KDNBF, a higher cost material, is 5 to 10 times more powerful than LMNR. BaSt is 80% as powerful but a better gas producer than KDNBF. Their Explosion Temperatures (°C at 5 sec) are 255-285° for LMNR, 250° for KDNBF, 250° and 341° for BaSt, while their Impact Sensitivities by 2-kg Drop Weight Test, are 45, 2 and 120cm]

68) C.L. Scott, "The Sensitivity of Selected Conventional and Heat Resistant Explosives at Low Temperatures", NOLTR 70-36 (1970), reviewed by G. Cohn, Edit in Expls&Pyrts 4(6), 1971 [The effects of temp, confinement, and column diam on the shock sensitivity were studied in a gap test arrangement for the following expls: Tetrol, CH-6, DNS-11, DIPAM (3,3'-Diamino-2,4,6, 2',4',6'-hexanitrophenyl), TACOT-Z (Tetranitro-1,2,5,6-tetrazadibenzyloctetetere) and TATB (1,3,5-Triamino-2,4,6-trinitrobenzene). Test temps were ambient and -68°C. As expected, sensitivity decreased with decreasing temp. These changes were small compared to the sensitivity effects of confinement and charge diameter]

69) Anon, "Fuze Catalog", MIL-HDBK-137, 20 Feb 1970. [Complete listing of military and technical info for all std and devel US items. Current fuzes (Vol 1), obsolete and terminated fuzes (Vol 2), fuze explosive components (Vol 3)]

70) B.M. Dobraetz, "Properties of Chemical Explosives and Explosive Simulants", Lawrence Livermore Laboratory, Univ of Calif Rept UCRL-51319 (Dec 1972) (AEC Contract W-7405-Eng-48) (A tabulation of names, formulations & props of various expls & energetic compds)

71) CG108, "Rules and Regulations for Military Explosives and Hazardous Munitions" (Revised annually), US Coast Guard, 400 7th St NW, Washington, DC 20591 [See Rules and Regulations for Explosives in General under EXPLOSIVES NONMILITARY (COMMERCIAL)]

72) Anon, "Explosive Trains", AMCP 706-179 (1973)

EXPLOSIVES NONMILITARY (COMMERCIAL) (Papers and Reports Listed in Chronological Order)

In addition to references listed in Vol 3 of Encycl on pp C456-R to C459, under COMMERCIAL OR INDUSTRIAL EXPLOSIVES and in Vol 5 on pp D1649-L to D1722-R, under DYNAMITE, the following may be included:

1) Atlas Powder Co, Fire and Water Eng 74, 151 et seq (1923) & CA 17, 3254 (1923) [Application of expls in checking large fires is discussed]

2) Bombrini Parodi-Delfino, FrP 793591 (1936)
butanol Nitrate, AN and other ingredients)
12) K.E. Riper, USP 2334149 (1943) & CA 38, 2824 (1944) (Explosives consisting of NG held within the pores of porous condensation product of urea and formaldehyde)
12a) F.R. Benson, PATR 1284 & 1287 (1943); 1338 (1943) & 1418 (1944) (Explosive scrap recovery)
13) R.W. Lawrence, CanadP 417844 (1944) & CA 38, 1644 (1944) (Explosion contg concd nitric acid and nitroparaffin, such as nitric acid 15–63%, nitromethane 85–37%)
14) C.H. Carey, USP 2345582 (1944) & CA 38, 4447 (1944) (An expl contg at least 60% AN, 5–12% of fatty materials, such as petrolatum and 5–25% carbonaceous material, such as starch, cereal flour etc and other ingredient and prep'd by a special method)
15) M.A. Cook & C.O. Davis, USP 2353147 (1944) & CA 38, 6098 (1944) (Explosive of high density is prep'd by heating a mixt of TNT, AN and a dispersing agent such as Na alkyl naphthalene sulfonate to a temp at which at least a portion of TNT is in molten condition)
16) C.O. Davis, USP 2358384 (1944) & CA 39, 1760 (1945) (Detonating explosives, such as AN 74.5, TNT 10.0, sulfur 2.0, woodpulp 6.0, a flaked corn product 7.0 and chalk 0.5%. Other mixtures may be used)
17) K.M. Gaver, USP 2389771 (1945) & CA 40, 1036 (1946) (Low density expl contg starchate of alkali metal or ammonia in which the metal is attached through an O atom to a C in the 2 position in the starch mol. Thiochloro, thioammonium or nitrostarches may also be used. E.g: NH₄ starchate, thiochloro, thioammonium 75 & NG 25%)
18) J. Whetstone, USP 2409919 (1946) & CA 41, 865 (1947) (Low density expls are prep'd by emulsifying easily melting expl (such as TNT) by a colloid (such as agar-agar or Na alginate) in a satd NH₄NO₃ soln contg solid AN in suspension (expl with higher mp such as PETN may be mixed with TNT). The mixt is congealed, granulated and dried at low temp)
19) H.R. Wright et al., BritP 577896 (1946) & CA 41, 1841 (1947) (Plastic explosive con-
sisting of a polynitrate ester, a nitroaromatic and NC)
20) J. Taylor et al, BritP 578371 (1946) &
CA 41, 1842 (1947) (Gelatinous expl suitable
for demolition purposes and as burning chge
for bombs, shells, etc is prepd by mixing a
jelled NG with TNT, stabilizer, etc)
21) J. Taylor et al, BritP 579376 (1946) &
CA 41, 1842 (1947) (Plastic explosives con-
sisting of a liquid nitrate ester and a 1:3
mixture of sol:isol Nitrocelluloses)
22) P.G.R. Bacon et al, BritP 580418 (1946)
& CA 41, 1841 (1947) (Plastic expls con-
sisting of 1:1 PETN:TNT plasticized with
PVC & dibutyl phthalate)
23) C.R.S. Harries et al, BritP 588885 (1946)
& CA 41, 1842 (1947) (Chopped and shredded
straw is incorporated in gelatin expls, such
as those contg NG & NC)
24) A.Ya. Apin & V.K. Bobolev, ZhFizKhim
20, 1367–71 (1946) & CA 41, 3297 (1947)
(The effect of physical structure and state
of aggregation on the sensitivity of expls)
(Engl translation OTIA 5377, AEC–n–3781)
InfoCirc 7380, 30pp (1946) & CA 41, 4309
(1947) (Handling, storage and use of expls
in mines and quarries)
26) P.W. Bridgman, "The Effect of High
Mechanical Stress on Certain Solid Explos-
27) G. Herzberg & G.R. Walker, Nature 161,
647–48 (1948) (Initiation of HE's)
& CA 42, 2105 (1948) (Expls; review with
59 refs)
29) A.F. Belyaev, ZhurFizKhim 22,
91–101 (1948) & CA 42, 5227 (1948) (Boiling
points, heats of vaporization and Trouton
constants of secondary expls)
43, 2435 (1949) (History of expls)
31) R. Saint-Guiliem, RevIndMinérale No 551,
791–810 (1949), No 552, 3–23 (1950) & CA
44, 5099 (1950) (Mining expls)
32) E.H. Buchanan, "Explosive Screw", PATR
1769 (1950) (See description earlier in
this Volume under Explosive Screw)
33) R. Leclercq, IndChimBelge 15, 3–10 (1950)
& CA 44, 5594 (1950) (Expls; review with
34 refs)
34) K.K. Andreev & M.A. Rabinovich, Zhur-
FizKhim 24, 650–61 (1950) & CA 44, 11097
(1950) (Mining explosives)
35) M.M. Thacker, H.O. Folkins, USP
2460200 (1949) & CA 45, 10565 (1951) (Addi-
tion of small quantities of explosives, such
as Ethyl Hypochlorite, TNT & Benzazide
to the hydrocarbons undergoing cracking,
increases the yields of desirable products,
permits carrying the reaction at lower temp
and in shorter time)
36) L.W. Braniff, WorldOil 131, No 7, 73–5,
90 (1950) & CA 45, 1345 (1951) (Expls for
seismographic prospecting for oil)
37) J. Tanaka, Reports of Osaka Prefecture
IndResearchInst 2, 27–33 (1950); Ibid 3, No 3,
5–12 (1951); Ibid 4, No 1, 32–6 (1952) & CA
46, 11743 (1952) (Explosives Used in Manuf
of Cellular Rubber) [Some primary expls, such
as Diazobenzonitrobenzene or Azides (of Ca, Ba
or Na) had been used in Japan as cellulating
agents in manuf of cellular rubber. For ex-
ample, 100 parts of crude rubber was thoroughly
mixed with 6ps of Diazobenzonitrobenzene,
C₆H₅N₂=N.H.C₆H₅, 6ps stearic acid, 3ps
ZnO, 3ps sulfur and 3ps tetramethyldiuron
disulfide, [(CH₃)₂NCS]₂S₂, and the resulting
mixture was vulcanized by heating 10 mins
at 115°C twice in succession in a press capa-
tible of exerting 20kg/sq cm pressure]
38) J.M. Downward, USP 2537039 (1951) &
CA 45, 2670 (1951) (Gelatinous expls of low or
zero NG content are prepd by adding 2–3%
of a non-expl gel, such as prepd by mixing
95% naphthene base oil (η₂₀ = 1000–2000
centipoises) with 5% of polyisobutylene as
a gelling agent)
39) B. Kubalov, VzryvnoeDelo 1949, No 43
& CA 46, 5843 (1952) (History of expl in
USSR in mining and construction)
40) H.C. Grimshaw, Ministry of Fuel and
Power, Safety in Mines Res Estab, Res Rept
No 34, 3–29 (1951) & CA 46, 6385–86 (1952)
(Slow burning of permitted expls as a possible
cause of hangfires or delayed expls)
41) H. Henkin & R. McGill, IEC 44, 1391–95
(1952) & CA 46, 8857 (1952) (Rates of expl
decompo of expls. Exp & theoretical
kinetic study as a function of temp)
42) A. LeRoux, RevIndustrMinérale 33, 276–84 (1952) & CA 46, 10623 (1952) (History of development of explosives industry)
43) P. Tavernier, MP 32, 239–53 (1950) & CA 47, 9014 (1953) (History of smokeless powder explosives)
44) E. von Herzen St & Jr, GerP 859868 (1952) & CA 52, 14171 (1958) (Decrease in sensitivity of gelatinous expls due to prolonged storage can be prevented by incorporating expls which are insol or only partly sol in expl oils. TNA and its derivatives are the most effective. Eg: a) NGc 28.5, NC 1.5 & TNA 70% — very brisk expl and b) NGc 47.5, NC 2.5, TNA 10 & AN 40% — medium brisk expl)
45) G.B. Kistiakowsky et al, USP 2606109 (1952) & CA 47, 4083 (1953) (Plastic non-hardening expl prep from 88% Cyclonite and 12% bodied or polymerized oil which may be distilled from sperm oil, rape seed or petroleum)
46) L. Méard, MP 32, 209–25 (1950) & CA 47, 9013 (1953) (Mining expls in France, review)
49) R.C. Clogau, USP 2674878 (1954) & CA 48, 13223–24 (1954) (Gelatinized high expl comps prep by incorporating in a blend of NG, NGc, NC, DNT, AN, K nitrate, carbonaceous material & sulfur, a small amt of a salt of triethanolamine and a higher fatty acid blended with at least one monohydric aliphatic alc contg 10–18 C atoms in the chain)
50) H. Zenfman & E. Whitworth, BritP 713758 (1954) & CA 49, 3537 (1955); USP 2716056 (1955) & CA 49, 15242 (1955) (Power to quench the expl flame is increased by incorporating some cryst salts in gelatinous expls based on NG=NC gel, AN, woodmeal, etc. In an example, 0.20 part p-tert-octylphenyl diethylphosphate and 3 parts o-MNT are dissolved in NG+NGc in the proportion 80:20 and to this NC (1.1 parts) is added. The resulting gel is mixed with other ingredients)
52) H. Selle, Explosivstoffe 3, 114–16 (1955) (Risks of ignition accompanying the breakage of low pressure vessels)
53) US Interstate Commerce Commission, "Transportation of Explosives and Other Dangerous Articles by Express, Including Specifications for Shipping Containers", Railway Express Agency, NY (1955), Suppl 1, 5
54) L. Méard, MAF 29, 669–88 (1955) (Safety of explosives)
56) A. Cachin, IndChimBelge 20, Spec No, 217–20 (1955) & CA 50, 6796 (1956) (Some permissible expls of the reduced density type)
57) B.P. Enoksson, USP 2736742 (1956) & CA 50, 6796 (1956) (Preparation of some nitratd organic products)
58) P.G. Wallerius, SwedP 152025 (1955) & CA 50, 7463 (1956) (Plastic expls from liquid organic nitrocompds, Al powder and inorg nitrates)
59) K. Namba, JIndExplSocJapan 16, 70–9, 132–43 (1955) & CA 50, 17451 (1956) (Explosives; review with 185 refs)
60) M.A. Cook & M.T. Abbeek, IEC 48, 1090–95 (1956) (Isothermal decomp of expls)
62) Kuhn & Käuffer, Explosivstoffe 4, 267 (1956) (The historical comprehension of the practical work and the mechanism of the behavior of explosives)
63) L. Méard, "Physics of Explosives",
MAF 31, 553–55, 556–69 & 570–83 (1957); 
Ibid 32, 911–52 (1958) and Ibid 33, 7–30 & 
31–58 (1959)
64) WASAG Chemie AG, GerP 1036137 (1958) 
& CA 54, 6833 (1960) (Exps of high mechanical 
strength prepd by working into expls, as 
carbon structures, organic fibrous substances, 
especially nitrited ones)
65) H.W. Koch & H. Freiwald, Explosivstoffe 
6, 279–84 (1958) (Pourable expls and determina-
tion of their viscosity)
66) H.P. Tardif, Materials in Design Engineering 
49, No 2, 82–7 (1959) (A roundup of pre-
sent applications of explosives to form, fasten, 
engrave & test)
67) P. Aubertin, MP 41, 111–25 (1959) 
(Stability of expls)
68) G. Boyd & A.C.P. McIntosh, AustralP 
213095 (1958) & CA 54, 16833 (1960) (Water-
resistant expls contain 0.2–6% lanolin)
69) K.K. Andreev, Explosivstoffe 8, 102–11 
(1960) & CA 54, 23330–31 (1960) (Thermal 
decompo & burning of expls)
70) N. Griffiths & J. Gnoock, JCS 1960, 
4154–62 and Explosivstoffe 11, 240 (1963) 
(Burning to detonation of solid expls)
71) L. Deffet, Explosifs 13, 103 (1960) and 
Explosivstoffe 12, 195 (1964) (Development 
of expls in Belgium)
72) R.W. VanDolah, IEC 53, No 7, pp 59A 
62A (Intern Ed 50A–53A) (1961) & CA 56, 
619 (1962) and Explosivstoffe 10, 249 (1963) 
(Evaluating the expl character of chemicals) 
(Available testing procedures prove to be 
inadequate for reliable results; difficult to 
test for the "unexpected" things people do 
with chemicals)
73) F.C. Gibson et al, "Sensitivity Character-
isics of Liquid Explosive Systems", US-
BurMineralsProgrRept No 3, July 1 to Sept 30 
74) N.S. Bakhaterevich et al, Vzryvnoe Delo, 
NauchnoTekhnGornoyeObshchestvo, Sbornik 
1962(49/6), 190–201 & CA 59, 3710–11 
(1963) (Permissible expls for mines with 
hazardous sulfide dust) (A mixture of w-
resistant AN, TNT, sawdust, ammonium 
chloride flame quencher and 0 or 9% liquid 
nitroester is permissible for use in a copper 
pyrite or similar mine with sulfide dust. 
With 9% nitroester the formulation (designated 
VS-1) is suitable for 1.25–1.40 inch car-
tridges, while up to 3.9 inch cartridges may 
be used with 0% nitroester (VS-2). For VS-1 and 
-2, respectively, the following props are 
found: heat of expln (kcal/kg) 742.16 and 718, 
brisance (mm) 17.26 and 14.5, distance of 
deton transmission (cm) 11 and 3.8, max 
charge for sulfide dust (gm) 450–600 and 
expansion in a lead bomb (ml) 280 and 260) 
75) Inspection Générale des Poudres 
C. 
Napoly, "Accidents at Explosives Plants", 
MP 45, 224–77 (1963) (Description of 69 
accidents which took place at various French 
expls plants during 1956–1960)
76) CanadIndsLtd, CanP 658221 and Kemixon 
Reporter, October 1963, p 1168, Item 10–614–3 
[Explosives in suspension such as AN 37.5, 
NaNO₃ 24.5, TNT (in pieces) 25.0 & carbon 
black 1.0 suspended in 12.0 parts water]
77) G.F. vonKrogh, Explosivstoffe 11, 275-L 
(1963) (Inexpensive expls with addn of watert) 
(Prepd from AN, sodium nitrate, sodium chloride, 
TNT, and thickened with guar gum, sodium 
CMC or sodium alginate)
78) F. Müller, Explosivstoffe 11, 269-R (1963) 
"Explosives in Powder Form With Reduced 
Sensitivity to Impact" [Addn of 0.1% of 4-
aminodiphenylamino-sulfonic acid to compo-
sition consisting of AN 80, NG 6, TNT 12 & 
woodmeal 2% changed its sensitivity to im-
 pact from 1.0mkg to 2.5mkg. In case of expl 
contg AN 82, TNT 11, Al 4 & woodmeal 3%, 
the addn of 0.1% of the above compd chan ged 
it's sensitivity to impact from 1.0 to 1.5mkg. 
The gap test value (Übertragungswerte) was 
not changed in the case of the 1st expl and 
increased only slightly in case of the 2nd 
expl (from 10cm to 11cm)]
Note: Accdg to Kemixon Reporter, Nov 1963, 
p 1312, Item 10–6189, the following compn was 
of Wasa-chemi, GerP 1143425: AN 82, TNT 
15, DNT 1 & woodflour 2% with added 0.05% 
of desensitizer, 4-aminodiphenyl amino-
sulfonic acid or 4,4'-diamino-diphenyl aminos-
sulfonic acid had impact sensitivity value 
using Koenen app 2.0m/kg, vs 0.75m/kg for 
the same expl without added desensitizer


81) Poudrerie Royale de Wetteren SA, BelgP 654268 (1965) & CA 64, 11022 (1966) (Flexible expls are prep'd from Nitroglycerin and/or Nitroglycerin with plasticized NC and red lead stabilizer. More flexibility can be had by adding dibutylphthalate)

82) PATR 2700, Vol 3(1966), p C500 (Note with 2 refs) (Construction of Buildings and Installations for Explosives and Propellant Plants)


84) H.H. Mohaupt, "Pelletted Ammonium Nitrate Blasting Explosives", USP 3301722 (1967) & CA 66, 87228 (1967) (AN 68, TNT 30, paraffin wax 2%, mixed and extruded under high pressure to give sp gr 1.4 pellets ¾-inch diam)


87) Gunther Cohn, Ed, Expls&Pyrts 4(8), 1971, "ON SHIPPING EXPLOSIVES" and in Vol 5(1), 1972, "MORE ON SHIPPING EXPLOSIVES". Shipping regulations are complex and a qualified shipper is needed to cope with them. The shipper must be properly licensed in all countries and in each US state involved. All cargo of hazardous material must be properly blocked and braced during shipment. For some hazard classes, the vehicle must be placarded and inspected. Mixed shipments in the same vehicle must be compatible. Whether shipment is planned by rail, truck, ship or air, it is desirable to follow the regulations for all modes of travel to avoid problems in case it is necessary to change the shipping mode.

All of the ref's below are updated periodically, most of them annually. Refs A-F are from Expls & Pyrots, G is an update of A, and H is an addl ref. More detailed information can be obt from Mr. William Byrd, Deputy Director, Dept of Transportation, Office of Hazardous Materials, 400 6th St, SW, Washington, DC 20590

Refs: A) Tariff 23, "Regulations for Transportation of Explosives and Other Dangerous Articles by Rail", published by Agent T.C. George, 2 Penn Plaza, New York, NY 10001
B) Tariff 11, "Regulation for Transportation of Explosives and Other Dangerous Articles by Truck", published by Agent F.G. Freund, American Trucking Assoc, Inc, 1016 "P" St, NW, Washington, DC 20036
C) CG108, "Rules and Regulations for Transportation of Military Explosives and Hazardous Munitons by Ship", US Coast Guard, 400 7th St, NW, Washington, DC 20591
F) Title 46, Parts 146-149 covers shipping by water and Title 14, Part 103, covers shipping by air
G) Tariff 25, "Hazardous Materials Regulations of the Department of Transportation", published by Agent R.M.

88) R.A. Dick, "Current and Future Trends in Explosives and Blasting". Pit and Quarry 64, Pt 1, No 1, July 1971, pp 159–62 & 174; Pt 2, No 2, Aug 1971, pp 105–07; reviewed by G. Cohn, Ed., in Expls&Pyrots 4(12), 1971. [This paper is an attempt to analyze current trends in the expl field and to project developments that are likely to occur in the near future. During the past 15 years, while inflation was steadily increasing, the costs of most phases of blasting operations in mining and construction work were steadily decreasing. This improvement in costs can be attributed to: 1) The continuing development of lower cost and more efficient blasting expls (such as ANFO and slurries); 2) The presently depressed price of AN; and 3) More inexpensive and efficient methods of loading these products. In future, continued reduction in blasting costs will be realized thru improved formulations of existing product types and more widespread use of bulk loading techniques. Dry blasting agents such as ANFO will continue their dominance in terms of product usage, while slurries will gradually increase their share of the market. Expl-based slurries will largely be replaced by alumined or other type slurries. Cap-sensitive slurries with small critical diams will replace Dynamos in many cases, and lower-energy, low-priced slurry products will be developed to compete with ANFO in some large-diam applications. Pneumatic loading of ANFO will find increased applications in open cuts and in underground mining, while bulk slurry loading, already widely used in large operations, will find increased application in small-diam work] 89) PATR 2700, Vol 5(1972), "Explosives of Apache Powder Co", Benson, Arizona 85602, are listed under DYNAMITE, Tables IV, VII, VIII, IX and X 89a) PATR 2700, Vol 5(1972), "Explosives of Trojan Powder Co", now known as "Trojan-US Powder", Division of Commercial Solvents Corp, 17 North 7th St, Allentown, Pa 18105, are listed under DYNAMITE, Class VIII & X 90) R.J. Buxton & T.M. Massis, "Compatibility of Explosives with Structural Materials of Interest", Sandia Laboratories", Aug 1970 & June 1972; reviewed by G. Cohn, Ed., in Expls&Pyrots 6(2), 1973 [Intended as an aid to the design engineer, the reports list 1500 structural material combinations and label them as compatible, incompatible, or marginal. The structural materials include: metals, plastics and adhesives, while the expls include: primary and secondary expls, propellants and pyrotechnics] 91) C.M. Mason & E.C. Aiken, "Methods for Evaluating Explosives and Hazardous Materials", BurMines Information Circular 8541 (1972). Reviewed in Expls&Pyrots 5(9), 1972 [The methods currently used by the Bureau of Mines to evaluate the sensitivity, strength, incendivity, gaseous products, and physical properties of explosives and hazardous chemicals are described. Included are the tests used to evaluate explosives which are certified as permissible for use in underground coal mines] 92) Capt H.H. Reed, "Slurry Explosives", Amv Res & Devel News Magazine, Vol 13, No 8, pp 22–3, Dec 1972. Reviewed by G. Cohn, Ed., in Expls&Pyrots 6(5), 1973 [SLURRY EXPLOSIVES. To comprehend fully the evolution of slurry explosives, one must start with the discovery that by adding fuel oil to pelletized ammonium nitrate, an excellent explosive for production blasts was obtained. As ammonium nitrate was a relatively inexpensive fertilizer, much safer and easier to work with than cartridgeed dynamosites, it soon gained wide acceptance in the drilling and blasting industry. The ammonium nitrate currently used in blasting is formed into a porous pellet called a prill. A mixture of 94.5% AN and 5.5% fuel oil was found to be the most efficient explosive and is termed ANFO. The addition of fuel oil allows all the available oxygen from the ammonium nitrate to be used effectively in the explosion. Unfortunately, ANFO is not without se-
several drawbacks, including its low density and its hygroscopicity (ability to absorb moisture). Paradoxically, it was found that thru the addition of water, with suitable stabilizing agents, and, if desired, gelling agents, not only are most of these problems overcome, but handling of the explosive is simplified. These water-based slurries or gels vary in consistency from a heavy paste or jelly to a solid rubbery mass, depending on the gelling agents used. The most common agent is a gum, such as guar gum. The gelling agent serves two purposes: (1) it insures a homogeneous mixture by preventing settling of components, and (2) it facilitates handling.

A simple slurry is one in which the fuel oil found in ANFO is replaced with another fuel which is compatible with a water gel. Most commercial slurries consist of an explosive base, such as ammonium nitrate or sodium nitrate, and a fuel, such as carbon, sulfur or aluminum. The addition of large quantities of aluminum produces a slurry with very high energy release at moderate detonation pressures.

The table indicates that both ANFO and slurries are excellent cratering explosives the effectiveness of which equals or exceeds TNT capabilities. Advantages are ease of field use, insensitivity to heat and shock – hence safe, voidless filling of holes, and low expense. Disadvantage is the need for a large booster charge for initiation.


94) O. Katsuki et al, KogyoKakaku 31(3), 131–7 (1970) & CA 78, 6073 (1973) (Combustion preventive chemicals for coal mine expls. I. Organic compds. Out of 60 compds tested only ammonium, sodium or potassium oxalate, potassium or potassium formate, and calcium tartrate were effective)

95) Y. Matsuguma et al, KogyoKakaku 33(4), 214–22 (1972) & CA 78, 6074 (1973) (Combustion preventive chemicals for coal mine expls. II. Inorganic compds. Effective compds were aluminum nitrate nonahydrate, aluminum sulfate octadeca hydrate and magnesium sulfate heptahydrate)

96) E. Samuelson, GerP Discl 2211527 (1972) & CA 78, 6091 (1973) (Water-containing expl mixes. An example is 87 parts of a suspension of guar gum 0.1, tapioca starch 0.4, EGC 1.5 parts with a soln containing AN 10, calcium nitrate (calcium nitrate 79, AN 6, w 15%) 45, sodium nitrate 4, urea 5, water 4 parts at 65°; and 13 parts of Polyball 295 O. 4 in EGC 75.2 parts at 80°, cooled, mixed with Al flakes 18 and powdered asphalt 9.4 parts; add 50% acq sodium dichromate 0.3 part when mixing the 87 and 13 parts to gel the mass)

97) P. E. Adams & P. W. Fearnow, USP 3678140 (1972) & CA 78, 6093 (1973) (Foaming aqueous,
protein-containing, blasting agents. An example is to slurry AN, sodium nitrate, water, methylamine nitrate, sugar, coal, sulfur and egg albumin with guar gum and EGc followed by extrusion thru orifices at 40-160 psi into a suction chamber to give sp gr of 1.05-1.08. 98) W.F. Clark, USP 3695950 (1972) & CA 78, 6094 (1973) (Amino-aldehyde resin blasting compn containing gaseous voids. An example is thiourea 10, sodium nitrate 10, AN 30, powdered Al 2½, 37% aq formaldehyde 10 parts, adjusted to sp gr 1.17 with glass microspheres). 99) W.F. Clark, USP 3695948 (1972) & CA 78, 6095 (1973) (Cast expl compn containing thiourea. An example is water 4.8, thiourea 19.1, AN 57.0, sodium nitrate 19.1%, adjusted to sp gr 0.90 with glass microspheres). 100) D.W. Edwards, USP 3695947 (1972) & CA 78, 6096 (1973) (Aq expl comprising a higher amine, a gelling agent, and an inorganic oxidizer salt. An example is 60% aq AN 200, modified guar gum 2.8, ethoxylated octadeylamine 2 gm). 101) H.E. Mager, GerP Disc 2211635 (1972) & CA 78, 18453 (1973) (Crystalline urea-containing expl mixture. Addition of AN 240, phenyl(dimethyl)amine 10, nitrophenol 10, and urea 500g to one liter of 50% nitric acid gives a non-hygroscopic expl mixture containing urea nitrate, polynitrophenol, polynitrophenyl dimethylamine, and AN and having deton vel of 3600-4200m/sec). 102) M. Vercauteren, USP 3684596 (1972) & CA 78, 18454 (1973) (Pulverulent and water-bearing expl mixtures. Prepd from water 0-2, liq hydrocarbon 3-6, and AN-KNO3 50-97%; the latter was prepd in the presence of fatty alkyl ammonium chloride and contributes low temperature detonability). 103) J.O. Goliger & R. Thiard, FrP 2102815 (1972) & CA 78, 18456 (1973) (Expl comps comprising heterogeneous granules. Composed of 15-60% 1-5mm TNT, Pentolite, or Cyclotol and 40-85% 1-5mm w-sol oxidizer such as AN or sodium nitrate). 104) M. Kluesch et al, GerP Disc 2126920 (1972) & CA 78, 45854h (1973) (Perchlorate-containing safety expls. An example is Al 25, AN 44.9, guar flour 0.1 and (methylamine-perchlorate 15, ethanolamine nitrate 43.4, methylamine nitrate 14.4, urea 14.4, AN 12.8%) 30%) 105) F.E. Slawinski, USP 3671342 (1972) & CA 78, 60376k (1973) (Dynamite compns containing expanded thermoplastic beads. An example is beads 1, 4:1 Nitroglycerol:Nitroglycerine 37.8, DNT 2.1, Nitrocotton 0.5, NC 0.3, AN 38.1, sodium nitrate 19.1, wood pulp 3.5, S 1.6 and chalk 1 part; such a mixture will explode under 500 feet of water). 106) M. Hamazaki & N. Nakajima, JapP 71 27937 (1971) & CA 78, 74350 (1973) (Expl compns for blasting concretes. Safety expls consist of Al or Al-Mg alloy 20-40, KNO3 20-50 and BaO 10-20 wt %). 107) E.A. Tomic, USP 3711345 (1973) & CA 78, 99994 (1973) (Chemical foaming of water-bearing expls. Addn of under 0.1% of a borohydrde to a typical gelled aq blasting agent containing a liquid carbonaceous fuel results in formation of stable 20-100 micron bubbles which sensitize the expl). 108) J.D. Chrisp, USP 3706607 (1972) & CA 78, 113851 (1973) (Chemical foaming of water-bearing expls. Sensitizing 20-60 micron bubbles are created in a typical gelled aq blasting agent by in situ oxidation of hydrazine). 109) E.A. Tomic, USP 3713919 (1973) & CA 78, 126468 (1973) (Chemical foaming of water-bearing expls with N3N-Dinitrosopentamethylenetetramine. A typical gelled or emulsified aq blasting agent is sensitized by addition of the Dinitrosotetramine blowing agent to form 10-100 micron bubbles). 110) C.G. Wade, USP 3715247 (1973) & CA 78, 126471 (1973) (Water-in-oil emulsion expl containing entrapped gas. An example is AN 31.7, NaNO3 10, Ethylenediamine Dinitrate 10, NH4ClO4 10, magnesium nitrate hexahydrate 12.3 and water 20 (heated until all dissolved), blended with a mixture of Indra 2119 wax 2 and sorbiron monololate 10 parts, followed by addition of Corcel hollow glass agglomerates to make 100 parts).
EXPLOSIVES, PHYSICAL TESTS AND ANALYTICAL PROCEDURES ARRANGED IN CHRONOLOGICAL ORDER

In addition to the books, pamphlets, papers and reports listed in Vol 5, pp D1649 & D1650 as references: 1, 2, 3, 4, 5, 6, 7, 8, 9, 9a, 10, 11, 12, 13, 13a, 13b, 13c, 13d, 14, 15, 16, 17, 18, 19 & 20 and under Foreign Methods of Examination, the refs 1, 2, 3, 4, 5 & 6, the following books, etc may be included as additional references:


B) E. de W.S. Colver, "High Explosives", Van Nostrand, NY (1918), pp 63 to 81 (Testing and Analyzing Raw Materials) and pp 228 to 40 (Testing and Analyzing Trinitroolene)


D) A. Stettbacher, "Schiess- und Sprengstoffe", Verlag A. Barth, Leipzig (1933), pp 361 to 375: "Die praktische Prüfungsverfahren für Sprengstoffe"

E) M. Giua, "Lezioni di Esplosivi, Parte Analitica", StabTipografico, L. Rattiero, Torino (1933)


G) L. Wöhler & C. Wenzelberg, MAF 14, 466-78 (1935) (Essais Nouveaux sur La Sensibilité au Choc des Explosifs)


I) J. von Meerscheidt-Hüllessem, SS 34, 167-70 (1939) & CA 33, 7569 (1939) (Determination of the chemical stability of explosives including smokeless propellants with the aid of Winkler gas buret)


K) E. Piantanida, "Chimica degli Esplosivi e dei Gas di Guerra", TipRAccademiaNavale, Livorno (1940), pp 302-29 (Various stability tests)

L) F.H. Goldman, JIndHygToxicol 24, 121-22 (1942) (Determination of content of expls, such as NG, DNT, TNT, Tetryn, PETN, etc in air by impinger method using suitable solvents)

M) G.D. Clift & B.T. Fedoroff, "A Manual for Explosives Laboratories", Lefax, Inc, Philadelphia, Vol 1 (1942): Chap I, Part 1 (Analysis of commercial mixed acids); Chap I, Part 2 (Analysis of oleums including those contg nitric acid); Chap I, Part 3 (Analysis of spent acids); Chap II, Part 1 (Laboratory practice); Chap II, Part 2 (Precise method of weighing); Chap II, Part 3 (Analytical method for the detn of nitrogen in nitroaromatic compds); Chap IV (Analysis of toluene used in manuf of TNT); Chap V (Trinitrotoluene tests); Chap VII (Detn of impurities in crude TNT); Chap VIII (Properties and analysis of MNT's, DNT's, Di-Oil (Commercial TNT), TNT's and commercial TNT); Chap IX, Pt 1 (Analysis of commercial nitric acid); Chap IX, Pt 2 (Analysis...
of commercial sulfuric acid and oleum); Chap X [Specification requirements and tests for DNT used in FNH (Flashless Non-Hygrosopic) propellant]; Chap XI, Pt 1 (Nitroglycerine and NG explosives); Chap XI, Pt 2 (Tests for NG); Chap XI, Pt 3 (Tests for NG expls); Chap XII, Pt 1 (Nitrocellulose and smokeless propellants, including the tests for raw materials); Chap XII, Pt 2 (NC tests and smokeless propellants tests); Chap XII, Pt 3 (Additional tests to be applied to any propellant) I; Chap XIII (Amatol); Chap XIV, Pt 1 (Picric Acid); Chap XIV, Pt 2 (Ammonium Picrate); Chap XV (Nitrostarch Explosives); Chap XVI, Pt 1 & Pt 2 (Tetryl); Chap XVII (Black Powder); Chap XVIII (Primers and detonators)

N) Ditto, Vol 3. Supplement Number One to Volume I (1943). Chap I (Analysis of acids including illustrations of Berl pipette and weighing pipette used at Keystone Ordnance Works, Meadville, Pennsylvania); Chap II (Various laboratory procedures); Chap IV (Analysis of toluene used for manuf TNT); Chap V (Analysis of TNT); Chap VI [Analysis of Sellite (Na sulfite soln) used for purification of crude TNT]; Chap VII [Analysis of "soda ash" (crude Na carbonate)]; Chap VI [Analysis of brimstone (crude sulfur) used for manuf sellite]; Chap VII [Analysis of Tri-Oil (crude TNT), yellow waters, and red waters formed during manuf of TNT]; Chap VII (Analytical procedures used at TNT waste disposal plant, described by Dr H.D. Minnig); Chap VIII (Detn of small amts of sulfuric acid in nitric acid and detn of small amts of nitric acid in sulfuric acid)

O) Ditto, Vol 3, Supplement Number Two to Volume I (1944). Chap I [Ammonia Oxidation Plant; Rapid method for estimation of ammonia in gases entering the converter; Laboratory control at Ammonia Oxidation Plant; Absorption tower efficiency; Ammonia oxidation conversion efficiency. Determination of small amounts of nitrogen oxides (Except N₂O & N₂O₃) in stack gases or in atmosphere]; Chap I (Pickling of platinum multilayer gauze); Chap I (Analyses of acids manufactured and used at TNT Plant); Chap I (Determination of efficiency of precipitators in Sulfuric Acid Concentration Plant); Chap II (Calibration of laboratory glassware); Chap II (Calibration of balances and weights); Chap IV (Determination of unsaturated compounds (olefins) in toluene); Chap V (Determination of sodium in TNT); Chap VI (Analytical procedures conducted at "Sellite" Plant); Chap VII (Analytical procedures conducted at Waste Disposal Plant); Chap VII (Tetranitromethane; determination in crude TNT and in other organic compounds); Chap XIV (Analysis of fuel oils used at Explosives Plants); (Analytical procedures conducted at Power House, such as analysis of coal and water); Chap XX (Toxicity of explosives and tests)

P) A.L. Olsen & J.W. Green, "Laboratory Manual of Explosive Chemistry", J. Wiley, NY (1943), pp 1 to 8 (Safety in laboratory organization); 9 to 20 (Propellants raw materials; testing and inspection); 20 to 24 (DuPont nitrometer); 26 to 32 (Testing Nitrocellulose); 32 to 50 (Smokeless propellants and their testing); 51 to 58 (TNT and testing); 58 to 60 (Amatol and testing); 60 to 66 (Picric Acid and testing); 66 to 70 (Ammonium Picrate and testing); 70 to 74 (Nitrostarch and testing); 74 to 81 (Tetryl and testing); 82 to 86 (Primers, Igniters & Initiators and testing); 87 to 91 (Black Powder and testing); 91 to 95 (Mercury Fulminate and testing); 95 to 97 (Lead Azide and testing); 98 to 101 (Sampling)

Q) Kast-Merz (1944). See Ref 3 on p D1650-R of Vol 5

R) Vivas, Feigenspan & Ladreda 4 (1946), Chapters II to XIV. See Ref 5 on p D1650-R in Vol 5 of Encycl

forms of the following expls and non-expl additives of expls: PETN, 2,4-DNT, TNT, PA, Ga Picrate, EDNA, NGu; 2,2,5,5-Tetranitromethylcyclopetanone; Dinitratohexahydro-1,3,5-trinitrotriazine; Octahydro-1,3,5,7-tetranitrotetrazine; 1-Acetylhexahydro-3,5,7-trinitrotetrazine; a,β-Diethylcarbamide, DPA, N-nitroso-DPA, 2-nitro-DPA; 2,4-dinitro-DPA; & 4,4'-Dinitro-DPA

T) L. Médard & M. Thomas, MP 31, 173-196 (1949) (Colorimetric determinations of 28 nitrocompounds and organic nitrates) [Included were: 2,6-DNT; 4,6-Dinitro-o-cresol; 2,6-Dinitro-p-cresol; 2,4,6-Trinitroaniline (Picramide); sym-Trimethynesylene (1,3,5-Trimethyl-2,4,6-trinitrobenzene); 2,4,6-Trinitroresorcinol (Styphnic Acid); 2-Aminetetrahydro-4,6-dinitrophenol; 2,4,6-Trinitrobenzoic Acid; 2,4,6,2',4',6'-Hexanitrodiphenylamine (Hexyl); 2,4,6-Trinitrophenylethylamine; Bis-(2,4,6-Trinitrophenyl)-ethylenedinitramine (Bietryl); Cyclotrimethylethenetritrosoamine; Ammonium Picrate; Nitroguanidine; Nitrourea; Urea Nitrates; Ethylenediamine Nitrate and Nitro-iso-butanetriol Trinitrate]

U) C. Caprio, "Corso di Esplosivi", Scuola Salesiana del Libro, Rome, Vol 2 (1949), 184-236 (Various stability tests); 238-39 (Chemical tests); 239-43 (Physical tests); 246-50 (Ballistic tests)

V) L. Médard, MP 33, 323-55 (1951) & CA 47, 10227 (1953) (Explosives, Testing). Brief descriptions of standard tests are given, along with typical values for important expls

W) C. Belgrano, "Gli Esplosivi", U. Hoepli, Milano (1952), pp 15 to 53 (Physical tests for mining explosives. Included are: density, stability, Traulz test, detonation velocity, Hess test, crusher test, sympathetic detonation test, sensitiveness to initiation, sensitiveness to impact, steel plate test and explosion temperature determination); pp 73 to 75 (Analysis of NG); 76 to 84 (Analysis of acids in NG manuf); 93 (Analysis of NGe); 96 to 97 (Analysis of PETN); 105 to 108 (Analysis of Collodion Cotton); 114 to 115 (Analysis of propellants); 119 (Analysis of DNT); 129 (Analysis of TNT); 135 (Analysis of RDXa, called T4 in Ital as conducted as for PETN described on pp 96-97); 161-68 (Analysis of AN and its explosives); 168 to 171 (Galleries for testing permissible expls); 171 to 172 (Measurement of duration and length of flame produced on explosion)


X) P. Aubertin, MP 37, 139-52 (1955) (Particle size measurements of expls) (Granulométrie)

Y) H. Koenen & K.H. Ide, Explosivstoffe 3, 89-93 (1955), 9 refs (Testing of explosives)

Z) P. Aubertin, MP 38, 29-37 (1956) (Analysis of phlegmatized explosives)


BB) Frank Priester et al, PATR 2254 (1956) (Analysis of explosives by IR spectrum method)

curves which differ from one another and from the single curve which the other six compts follow. By testing different amounts of sample to generate a curve it is possible to identify the HMX or RDX and quantitatively measure it by comparison with a standard for each.

KK) Michele Giua, "Trattato di Chimica Industriale", UTTE, Torino, 6(1) (1959) [Includes on pp 433 to 463 - Physical Tests, which include: impact test, Trazul test, sand test, sensitivity to initiation, decomposition temperature, detonation velocity by methods of LePoulangé, Dautrieve and Metregang; sympathetic detonation or gap test; rifle bullet test; length and duration of flame test; gallery tests; specific weight determination; heat tests; such as of Abel, Angeli, Bergmann-Junk, Waltham Abbey (Silver vessel test); Grottanelli, Guttman, Hess, Hoitsema, Mayrhofer, Obermüller, Sy, Taliani, Thomas, Vieille and Will. On p463 to 475 are Chemical Analyses of various explosive compts, explosive compons and propellants. On pp 475 to 488 are Microscopic Analyses which include 72 microscopic photos of crystals. On pp 488 to 494 is given a brief description of analyses of acids used in nitration, of raw materials and of nonexpl substances used as ingredients of various expl compons.]

LL) F. Pristera et al, PATR 2254 (1956) (Analysis of Explosives by Infrared Spectroscopy). A compilation of 68 infrared spectrograms covering all common HE's and many possible expl ingredients, additives and related compts. In the analysis of single or multi-component HE's, infrared spectroscopy is, in most cases, very useful either alone or in connection with other methods. Infrared spectroscopy has the advantages of speed, specificity and very often accuracy & precision.
NN) Anon, "Analytical Methods for Powders and Explosives", AB Bofors, Nobelkrut, Sweden (1960) lpp 42-60 - Stability tests; 60-62 - Explosion temperature test; 63-65 - Explosive character tests, which includes Trauzl-, impact-, and detonation velocity tests; 67-155 - Examination of raw materials for propellants, explosives and pyrotechnics; 159-164 - Examination of nitrated products; 165 - Examination of nitration acids; 167-191 - Examination of finished products: propellants, secondary expls and primary expls; 192 - Examination of individual expls: solid TNT, liquid TNT, Hexogen (RDX), Hexotol (Cyclotol), Hexotonal (RDX/TNT/Al, Torpet), Pentrite (PETN), Bofors Plastic Explosive (BPE), Bonocord, Tetryl, Lead Azide, Lead Styphnate, Mercury Fulminate, Silver Azide and Tetraene. 

O0) M. Roth of Picatinny Arsenal, "Current Accomplishments on Analytical Chemistry Project on Evaluation and Establishment of Methods of Analysis of Propellants, Explosives and Chemical Ingredients", Presented at Third Meeting of Operations Subcommittee to the Integration Committee on Propellants and Explosives, US NOTS, China Lake, Calif, 16 March 1960 (Following are some accomplishments: a) Modification of DuPont nitrometer by introducing a 2-part bulb. This bulb is recommended for use with PETN and Nitrogrenadi (NGU) (abbr NQ by Roth): This modification is described by M. Roth et al in PATR 2579 (1958); b) Introduction of "titanous chloride-buffer method" for detn of NGUs in propellants. This method is described by M. Roth & R.F. Wegman in Anal-Chem 30, 2036 (1958); (See Addl Ref HH); c) Improved method for detn of stabilizer content. The method is described by M. Roth et al in PicArsnTechMemo No GL-6-59 (See Addl Ref II); d) Improved colorimetric method of analysis of binary mixtures of nitrate and nitramine or nitramine alone. This method described by M.A. Laccetti et al in AnalChem 31, 1049-50 (1959) gave good results in analysis of RDX-HMX mixtures (See Addl Ref JJ); e) Development of a volumetric method for RDX as well as other expls, based on reduction by cbromous chlorid. A noteworthy feature of methods employing this reagent is that the reaction proceeds at room temp. The description of method was not given in open literature as of 1960; f) Among the instrumental methods used at PicArsn for quality control work, absorption spectrophotometry was found the most useful type of measurement. Some spectra have been published by F. Pristera et al in PATR 2254 (1956) (See Addl Ref LL); g) Evaluation of tetraphenylboron method for the determination of potassium.

OOa) Ye.Yu. Orlova, "Khimiya i Tekhnologiya Bizantnykh Vzryvchaykhs Veshchestv" (Chemistry and Technology of High Explosives), GosizdatOborProm, Moscow (1960) (No tests for explosives or propellants are described).


PPa) A.H. Rosen & H.T. Simmons, NAVORD Rept 6629 (1959), US Naval Ordn Lab, White Oak, Md. This rept describes an improved constant temp block used to study the stability & compatibility of expls at elevated temps. A very small area of the heating block is exposed while introducing or removing a sample from any one of 12 sample positions; achieved by means of a rotating top. A single piece all glass unit consisting of a sample tube & manometer is described for making vacuum stability measurements at elevated temps.


SS) I. Dunstan & J.V. Griffiths, "Determina-
Course in the Theory of Explosive Substances" (in Russ), RosVuzIzdat, Moscow (1963)


General Methods (pp 1286 to 1305)

Heat of Explosion Determination (1286–88)
Hygroscopicity of Propellants (1288–89)
Moisture by the Carbon Tetrachloride Distillation Procedure (1289–90)
Moisture by Karl Fischer Titration (1290–93)
Moisture and Volatiles by Oven Drying at 100°C (1294)

Moisture and Volatiles by Vacuum-Oven Drying at 55°C (1294)

Nonaqueous Titration (1294–95)

Stability by International Test at 75°C (1295)

Stability by Potassium Iodide-Starch Test. See pp 1333 under "Stability Test: Heat Test with Potassium Iodide-Starch Test"

Stability by Heat Test at 120°C or 134.5°C With Standard Methyl Violet Paper (1295–96)

Stability by Surveillance Test at 65.5°C (1296)

Stability by the Taliant Test for Propellants (1296–97)

Stability by Vacuum Stability Test for Propellants or Ingredients (1297–99)

Strand Burning Rate of Solid Rocket Propellants (1299–104)

Total Volatiles by the Solution Evacuation Procedure. See footnotes 29 & 30, p 1375

Titrmetric Calculations (1304–05)

Ingredients of Explosive and Propellant Compositions (1306 to 1344):

<table>
<thead>
<tr>
<th>Composition</th>
<th>Speciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum</td>
<td>(1306–07)</td>
</tr>
<tr>
<td>silicon</td>
<td>(1308)</td>
</tr>
<tr>
<td>zinc</td>
<td>(1308)</td>
</tr>
<tr>
<td>iron</td>
<td>(1308–09)</td>
</tr>
<tr>
<td>magnesium</td>
<td>(1309)</td>
</tr>
<tr>
<td>copper and lead</td>
<td>(1309–10)</td>
</tr>
</tbody>
</table>
tion of Carbon Content by Wet Combustion: Application to Explosives and Initiators", ERDE Tech Memorandum No 2/W/62 (1962), OTIA 18588

TT) E. Haeuseler, Explosivstoffe 10, 97–104 (1962). Melting point apparatus are described and compared in determining the mp's of various expls and non-expls. The Thiele Tube, which uses a liquid or molten salt bath surrounding a capillary tube containing the substance and attached to a thermometer, is represented by the Tottoli improvement; this incorporates steepless internal electrical heating and a stirrer. The Maquenne Block represents the electrically heated metal surface (2.6 x 25cm) type, on which one places the substance; to hold down sublimation and decomposition effects, the block is heated to the vicinity of the expected mp, and then samples of the substances are periodically placed on the block as the temp is further raised. The Kofler Block is a metal surface 3.8 x 37cm with a fixed temperature gradient of 50–260°; the substance is linearly spread on it in the expected mp region. Accuracy with the latter is considerably lower than other methods, only ± 0.4–1.0°. When small amounts of the substance are available, the Hilbck Micro Hot Stage is used. The substance is placed between cover glasses sandwiched between two heated metal discs, both having holes in the center. A low power microscope is used to observe the mp thru the upper hole, illumination entering from the lower. Except for the Kofler method a collection of narrow range thermometers is required for careful work.


Section 100 (Methods 101 to 118). Specification Tests of Single Component Explosives: Ammonium Picrate (Explosive D), Diazodinitrophenol (DAzDNPh, Dinol, Diazol), Dinitroethylbenzene (DNEB or DNetBz), Dinitromethylaniline (DNMA or DNMAn), DNMA in Sulfuric Acid, Dinitrotoluene (DNT), Halite (EDNA), HMX (Cyclotetramethylene-tetranitramine), Lead Azide (LA), Lead Styphnate, Basic (LSt, B), Lead Styphnate, Normal (LSt, N), Mercury Fulminate (MF), Nitroguanidine (NGu, Picrite), Pentazethro- tol Tetranitrate (PETN), RDX (Cyclonite, Cyclotrimethylene-nitramine, Hexogen), Tetranitromethane (TeNCmz, TeNC), Tetryl (Trinitrophenylmethylnitramine) and TNT (Trinitrotoluene Trietyl)

Section 200 (Methods 201 to 212). Specification of Multiple Component Primer Compositions: Fuze Powder; Primer Mix, US Standard; Primer Mix, New No 4; Primer Mix, MK V; Primer Mix, No 70; Primer Mix, PA100 Primer Mix, NOL No 130; Primer Mix, M3 Ignition Cartridge; Primer Mix, M29 Percussion Primer; Priming Composition, Lead Starter Type; RDX Booster Pellets; and Tetryl Booster Pellets

Group 100: General Test Methods
Group 200: Physical Test Methods
Group 300: Sample Preparation
Group 400: Chemical Test Methods
Group 500: Stability Sensitivity and Surveillance Tests
Group 600: Standard Solutions
Group 700: Standard Indicators


XX) A.F. Williams & D. Kenyon, Explosiv-stoffe 11, 249 (1963) (Application of cathode-ray polarography to analysis of mining explosives)


ZZ) A. Gol' binder, "Laboratory Works for a
expls & proplats; b) Determination of acidity; c) Pressure and volume change measurements; and d) Weight loss determinations}

CD) T. Urbański, Vol 2(1965), pp 22–31 gives methods for determining the Stability of Nitric Esters, which include: Abel Heat Test, Litmus Test (Vieille Test), Heat Test at 134.5°C, Silvered Vessel Test, Loss of Weight Test, Will Test, Bergmann & Junk Test and Manometric Test

DE) A.A. Menegus, Ordn 49, 86–8 (1964) (Explosives, Testing by TV). Closed circuit TV is used at Picatinny Arsenal to observe laboratory prep of new expls, mechanical shaping of solid expls, field testing of ordnance items, recovery and disposal of misfires, etc. By remote control the camera lenses may be directionally oriented, especially in conjunction with operation of remote control "slave" devices and vehicles

EF) C. Giorgio, "Tecnica degli Esplosivi", Del Bianco, Udine (1964), Chap IV, Physical Tests (pp 41 to 56), which include: Detonation velocity (42–8); Pressure of explosion (49–53); Volume of gases of explosion (53–4); Heat of explosion (54–6). Chemical Analyses (56–58), which include: determinations of mp, impurities, acidity, alkalinity, carbon by combustion, and separation of ingredients by various solvents. Stability Tests (56–66); Hygroscopicity (66); Freezing (66); Exudation (67); Explosion temperature (67–8); Sensitivity to flame and to high temperature in general (68–9); Sensitivity to impact (70–2); Sensitivity to initiation (72–3); Efficiency of initiators (73–4); Sensitivity to rifle bullet (74); Power of explosives by Lead Block Test (75–81); Brisance by Hess' method (81–2); Brisance by Hess' modification (82); Brisance by Kast’s method (82–3); Swedish test for use in mining (86); Ballistic pendulum and Ballistic mortar (86–93); Ballistic pendulum of Schmidt (93); Ballistic pendulum for measuring impulse and shattering (93–4); Steel plate breakage test (94–5); Gap test (95–6); Gallery tests for permissible explosives (esplosivi grisoutosi) (96–8); Study of flame produced on expln (98–100); Propagation of detonation wave (100–101)

FG) W. Selig, "Some Analytical Methods for Explosives and Explosive Simulants", UCRL-7873, pp 1–65 (1964) & CA 64, 9497–99 (1966). Describes the estimation of RDX & HMX by nonaqueous titrmetry; analysis of HMX, Poly (2,2-dinitropropylacrylate, silica, and ethyl & methyl 4,4-dinitropentanoate in expls; determination of PETN & silica in LX-02-1; spectrophotometric detm of acetyl tributyl citrate in extrudable expl LX-02-1; analysis of a mixt of HMX, Viton & oxamide; analytical procedure for RDX in RX-05; analysis of tungsten & HMX in RX-12; analysis of a mock expl 90010; analysis of a mock material for LX-0-4-1; and determination of cyanuric acid, melamine, and Vicon in mixt LM-04-0

GH) A.J. Clear, "Standard Laboratory Procedures for Determining Sensitivity, Brisance and Stability of Explosives", PATR 3278 (1965), FREL, Picatinny Arsenal, Dover, NJ. The following tests are described: Impact Test with PicArsn Apparatus (pp 2 to 4 with Figs 1, 2, 3 & 4 on pp 32 to 35); Impact Test with USBurMines App (4 to 7 with Figs 5, 6 & 7 on pp 36 to 38); Modified Impact Tests for Liquid Explosive Made with BurMines App and with PicArsn App (7); Explosion Temperature Test (7 to 8 with Fig 8 on p 39); Decomposition Temperature Test (8); Sensitivity to Initiation as determined by Sand Test (9–11 with Figs 9, 10, 11 & 12 on pp 40–3); Modified Sand Test for Liquid Explosives (12–14); Electrostatic Sensitivity Test (14–15 and Figs 13 & 14 on pp 44 & 45); Brisance by Sand Tests (16–17); Initiation Efficiency by Sand Test (17); Stability Tests, which include: 75°C International Test (18); 82.2°C KI Test (19); 100°C Heat Test (19); 90°, 100° & 120°C Vacuum Stability Tests (19–22 and Figs 15, 16 & 17 on pp 46–8); 65.5°C Surveillance Test (22–3 and Fig 18 on p 49); 80°C Surveillance Test (23); 120° and
134.5°C Heat Tests (23-5); Taliani Test (25-7 and Fig 19 on p 50); 65.5°C KI Test (27-9 and Fig 20 on p 51); and Reactivity Tests (29-31)

Hi) S. Fordham, "High Explosives and Propellants", Pergamon Press, NY (1966), Chapter 6, "Assessment of Explosives", which includes: Power or Strength (pp 65-8); Velocity of Detonation (69-72); Sensitiveness to Friction and to Impact (72-6); Sensitiveness to Storage (76-8); Fume Test (78-9); and Miscellaneous Tests, such as for Brisance and Speed of Gelatinization of NC (79-80). Chapter 7: Gallery Testing of Permitted Explosives (85-9)


Kl) Anon, "Military Explosives", TM 9-1300-214/TO 11A-1-34 (1967). Chapter 5, Properties and Tests of High Explosives: Sensitivity to Frictional Impact (pp 5-1 to 5-3); Sensitivity to Friction (5-3 to 5-6); Sensitivity to Frictional Impact (5-6); Sensitivity to Heat and Spark, which includes Explosion Temperature Test (5-6 to 5-9); Sensitivity to Initiation (5-9); Stability Tests, which include 75°C International Test, 100°C Heat Test, Vacuum Stability Test and Potassium Iodide-Starch Test (5-9 to 5-15); Brisance Tests which include Sand Test, Plate Dent Test and Fragmentation Test (5-15 to 5-18 and Fig 5-13 on p 5-19); Initiating Value (5-18 & 5-20); Sympathetic Detonation (5-20 to 5-21); Power which includes Heat of Explosion Test, Ballistic Pendulum Test and Trauzl Lead Block Test (5-21 to 5-24); Blast Effect (5-24 to 5-27); Cratering Effect (5-28 & 5-29); and Munroe-Neumann Effect (5-29 to 5-35)


Mn) D.P. Lindstone, "The Assessment of Explosive Performance by Means of a Cartridge Case Deformation Test", Explosivstoffe 17(9), 193-201 (1969). Abstracted in Explos&Pyrots 3(8), 1970 [Two-gram charges are fired in brass small-arms cartridge cases (cal .303) and results compared with a cartridge in which a 2-g "standard" was fired]


Op) J. McCamock et al, "A New Procedure for the Estimation of the Impact Sensitiveness of Explosives", Explosivstoffe 17(10), 225-28 (1969). Abstracted in Explos&Pyrots 3(8), 1970 (Measurement of the Figure of Insensitiveness for relatively insensitive expls by the drop weight method is improved by detecting gas evolved in "no-fires" with starch-iodide impregnated filter paper. Quantities of gas less than 1 cc are readily detected)

Pq) M.F. Zimmer & L.D. Lipton, "Dynamic Pressure Measurements on Small Amounts of Detonating Lead Azide", Explosivstoffe 18, 12-15(1970). Abstracted in Explos&Pyrots 3(8), 1970. (To evaluate the safety of handling small (few mg to 1 g) amts of LA in daily pilot plant operations, dynamic pressure measurements were taken with/without protective cloth. The distance from the sample to the gauge was changed from 1 to 30cm)

Qr) M. Cuchaud, "On the Sensitivity of Explosives to Mechanical Effects", Explosivstoffe 18(1), 16-19 (1970) (in French). Abstracted in Explos&Pyrots 3(8), 1970 (Various theories attempting to explain the initiation of expls by a falling weight are briefly presented along with refs to reported expls
under other circumstances which suggest a multiplicity of causative effects. The author then proposes that the underlying basis for any initiation is the attainment of a local electrical polarization in the expl which meets the "critical" value for that expl in the particular conditions at hand.

R.S. R. Jenkins & H.J. Jallop, "The Identification of Explosives in Trace Quantities on Objects Near an Explosion", Explosiv-stoffe 18, 139-41 (1970). Abstracted in Expls&Pyrots 4(3), 1971 (Samples are taken by rubbing the object with cotton wool soaked in a solvent appropriate for the suspected expl, then extracting the cotton with more or a different solvent. The concentrated extract is then chromatographed on a thin layer of silica gel along with samples of known expls. The developed chromatograph is dried and then sprayed with any of four reagents which give distinctive colors for MNT, DNT, TNT, NG, AN, NGu, NC, RDX, HMX, PETN, or Tetryl. The color, in combination with the position of the colored spot on the chromatograph, will define the expl)

405-408, Handling of Explosives
406 & 407, Table 1. Properties of Primary Explosives
408-10, Mercury Fulminate (MF) and Analyses
410-13, Lead Azide (LA) and Analyses
413-16, Lead Styphnate (LSr) and Analyses
416-17, Diazodinitrophenol (DADNPh) and Analyses
418-Table 7, Interplanar Spacings of Primer Ingredients in Approximate Order of Intensity, Å
419-21, Characteristics and Reactions of Individual Primer Ingredients
421-24, Analysis of Unknown Primer Compositions
424-31, Determination of Components in Known Primer Mixtures
424, Table 8, Composition of Ten Typical Primer Mixtures
431-51, High Explosives
432-33, Table 9. Physical Properties of Commercially Important High Explosives
446-50, Table 20. Common High Explosive Mixtures
451-52, Salts (Ammonium Picrate, Nitrate and Perchlorate)
452-60, Method of Analysis by Infrared Spectroscopy
460-62, Analysis of Unknown High-Explosive Mixtures
461, Table 22. Ingredients in Order of Increasing Melting Points
462, Table 23. Solubility of High Explosive Ingredients in Four Selected Solvents
463-65, Nitrogen Content of Nitrate Esters by Gas Evolution Using DuPont Nitrometer
465-66, Nitrogen Content of Nitrate Esters by Ferrous Reduction
466-67, Nitrogen Content of Nitro Aromatics by Titanous Reduction
467-70, Other Methods for Quality Control (Ash Content, Moisture, Bulk or Apparent Density, Specific Gravity by Mercury Displacement, and Solidification Point)
470-71, Sixtyn-seven References

TU S. Semel, "Detection of Concealed Explosives", SMUAP-FT-E-C, PicArsn, Dover, NJ (1973). Reviewed in Expls&Pyrots 6(4), 1973 (An experimental study has been completed on the feasibility of fast neutron activation for detecting concealed explosives in baggage. The same approach was first investigated by the North American Rockwell Corp, Los Angeles for the Federal Aviation Administration. The latter work was directed to the measurement of gamma radiation produced by activation of nitrogen in explosives. However, its feasibility for explosives detection is severely limited by the large number of false alarms due to the activation of common components in luggage which results in the same radiation as that from nitrogen. The method has now been extended by measuring the gamma rays from the neutron activation of both nitrogen and oxygen using two distinct detector channels. In this manner,
the probability of detecting the presence of an explosive is greatly increased with a corresponding decrease in the false alarm rate.

UV) A.G. Gorst, "Porokha i Vzryvchatyiye Veshechestva" (Propellants and Explosive Substances), 3rd ed., IzdatMashinostrojeniya, Moscow (1972). Chapter II. Stability and Methods of Its Determination, which include: Abel Test (pp 32–3); Vieille’s Test (33); Loss of Weight Test (33); Manometric and Electrometric Tests (34). Chapter III. Initiation of Explosives by the following methods: Heat or Flame (38–9 with Table 5 on p 59 giving Ignition Temperatures of various expls); Initiation by Mechanical Action, such as Impact Test (40–3); Friction Sensitivity by Method of Bowden-Kozlov (43–4); Initiation by Blasting Caps and Detonators (44); Detonation by Influence by Gap Test (44–5). Chapter IV: Heat of Explosion (49–51); Temperature of Explosion (51–3); Volume of Gases Produced on Explosion (58–9); Pressure of Gases Produced on Combustion and Explosion (59–61). Chapter VI. Determination of Detonation Velocity by Dautriche Method (80–1); Determination of Capacity for Work (Fugasnoye Deystviye or Fugasnost’ in Russ) (Fugacity). He uses for these tests Ballistic Pendulum, Trauzl Block, Cratering Action and Explosion of Artillery Projectiles (88–91); Brisance by Compression of Lead Cylinder (92–3); Action of Shaped Charge Explosions (Kumulyativnoye Deystviye Vzryva, in Russ) (93–5)


There are also descriptions of physical tests and analytical procedures under explosives of military or commercial interest and of raw materials. If any US Military Specifications are issued, their requirements and tests are described

Following is a selected list of US Military Specifications, arranged in alphabetical order:
### TABLE OF US SPECIFICATIONS

<table>
<thead>
<tr>
<th>Material</th>
<th>Abbreviation or Formula</th>
<th>Specification</th>
<th>Date</th>
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<tbody>
<tr>
<td>Acetic Acid</td>
<td>AcOH</td>
<td>JAN-A-465</td>
<td>April 1947</td>
</tr>
<tr>
<td>Acetic Anhydride</td>
<td>Ac₂O</td>
<td>JAN-A-459</td>
<td>March 1947</td>
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<td>Acetin or Triacetin</td>
<td>Tec</td>
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<td>Acid, Acetic</td>
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<tr>
<td>Acid, Mixed</td>
<td>MA</td>
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<td>Dec 1968</td>
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<td>Acid, Nitric</td>
<td>NA</td>
<td>JAN-A-183(2)</td>
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<td>Acid, Picric</td>
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<td>JAN-A-187</td>
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<td>Acid, Sulfuric</td>
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<td>JAN-A-179</td>
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<td>Adhesive &amp; Sealing Compounds,</td>
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<td>Cellulose Nitrate Base, Solvent Type,</td>
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<td>Alpha-Nitronaphthalene</td>
<td>α-MNN</td>
<td>MIL-A-23894</td>
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<td>(For Use in Explosives)</td>
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<td>Aluminum Powder, Spherical</td>
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<td>Aluminum, Powdered, Flaked,</td>
<td>Al</td>
<td>MIL-A-512A(2)</td>
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<td>Grained, and Atomized</td>
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<td>Ammonia, Technical</td>
<td>Amm</td>
<td>O-A-445A</td>
<td>Jan 1961</td>
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<td>Ammonium Hydroxide, Tech</td>
<td>AmmH</td>
<td>O-A-451E</td>
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<td>Ammonium Nitrate, Prilled</td>
<td>AN</td>
<td>MIL-A-50460(1)</td>
<td>July 1972</td>
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<td>Ammonium Perchlorate</td>
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<td>MIL-A-23442A(1)</td>
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<td>Ammonium Perchlorate for Solid Proplnt</td>
<td>AmmPer</td>
<td>MIL-A-23946(1)</td>
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<td>Grains Mark 75 and Mark 76</td>
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<td>Ammonium Perchlorate, Special Coarse</td>
<td>AmmPer</td>
<td>MIL-A-23948(1)</td>
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<td>for Solid Proplnt Grains Mark 75</td>
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<td>and Mark 76</td>
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<td>Ammonium Perchlorate, Tech</td>
<td>AmmPer</td>
<td>MIL-A-192B</td>
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<td>Antimony Sulfide (For Use in Ammunition)</td>
<td>Sb₂S₈</td>
<td>MIL-A-159D</td>
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<td>Asphaltnit (Gilsonite)</td>
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<td>June 1946</td>
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<td>Barium Carbonate (For Use in Ammunition)</td>
<td>BaCO₃</td>
<td>MIL-B-624A</td>
<td>April 1969</td>
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<td>Barium Chromate</td>
<td>BaCrO₄</td>
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<td>Barium Nitrate, Technical</td>
<td>Ba(NO₃)₂</td>
<td>MIL-B-162D</td>
<td>Feb 1968</td>
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<td>Barium Oxalate (For Use in Ammunition)</td>
<td>Ba(C₂O₄)</td>
<td>JAN-B-660</td>
<td>Aug 1948</td>
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<td>Barium Peroxide</td>
<td>BaO₂</td>
<td>MIL-B-153A(1)</td>
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<td>Barium Stearate</td>
<td>Ba(C_{18}H_{35}O_{2})</td>
<td>JAN-B-366</td>
<td>July 1946</td>
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<tr>
<td>Binder, Cellulose Nitrate Camphor (For Pyrotechnic Mixtures)</td>
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<td>MIL-B-10854</td>
<td>Jan 1951</td>
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<td>Butyl Acetate, Normal (For Use in Org Coatings)</td>
<td>n-BuAc</td>
<td>TT-B-838A</td>
<td>Aug 1959</td>
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<td>Butyl Acetate, Secondary (For Use in Org Coatings)</td>
<td>sec-BuAc</td>
<td>TT-B-840B</td>
<td>Jan 1960</td>
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<td>Butyl Alcohol, Normal (For Use in Org Coatings)</td>
<td>C_{4}H_{9}OH</td>
<td>TT-B-846B</td>
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<td>Butyl Alcohol, Secondary (For Use in Org Coatings)</td>
<td>sec-C_{4}H_{9}OH</td>
<td>TT-B-848B</td>
<td>Dec 1959</td>
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<td>Butyl Stearate, Normal</td>
<td>C_{18}H_{35}COOC_{4}H_{9}</td>
<td>MIL-B-21465</td>
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<td>Cadmium Oxide</td>
<td>CdO</td>
<td>MIL-C-6151A</td>
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<td>Calcium Carbonate</td>
<td>CaCO_{3}</td>
<td>MIL-C-00293A</td>
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<td>Calcium Resinate</td>
<td>CaSi_{2}</td>
<td>MIL-C-20470A</td>
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<td>Calcium Silicide</td>
<td>Ca(C_{18}H_{35}O_{2})_{2}</td>
<td>MIL-C-324B</td>
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<td>MIL-C-306B(2)</td>
<td>Jan 1968</td>
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<td>Carbon Black (For Use in Explosives)</td>
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<td>CA</td>
<td>Nov 1951</td>
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<td>Cellulose Acetate (For Use in Propellant Powder)</td>
<td>CA</td>
<td>MIL-C-20301</td>
<td>Nov 1951</td>
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<td>Cellulose Nitrate (Pyroxylin) Rods (For Use in Ammunition)</td>
<td>NC</td>
<td>JAN-C-801</td>
<td>June 1949</td>
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<td>Cellulose, Cotton (For Use in Explosives)</td>
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<td>MIL-C-206A</td>
<td>Aug 1962</td>
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<td>Cellulose, Regenerated, Strip (For Use in Ammunition)</td>
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<td>JAN-C-677(2)</td>
<td>Dec 1951</td>
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<td>Charcoal (For Use in Ammunition)</td>
<td>C</td>
<td>JAN-C-178A(1)</td>
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<td>Composition B</td>
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<td>MIL-C-401C(2)</td>
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<td>Composition B4</td>
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<td>Composition C3</td>
<td>Comp C3</td>
<td>MIL-C-427A</td>
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<td>Composition CH-6</td>
<td>Comp CH-6</td>
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<td>Composition D2</td>
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<td>Composition 85/14 RDX/Wax</td>
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<td>Composition, Delay</td>
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<td>Composition, Tracer, R-45 Igniter, K-29</td>
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<td>MIL-C-14334</td>
<td>June 1956</td>
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<td>Composition, Tungsten, Delay</td>
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<td>MIL-C-48141</td>
<td>March 1973</td>
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<td>Compositions A3 and A4</td>
<td>Comp A3 &amp; Comp A4</td>
<td>MIL-C-440B</td>
<td>July 1961</td>
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<td>Copper (99.0% Min Cu)</td>
<td>Cu</td>
<td>AMS-4740</td>
<td>Jan 1971</td>
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<td>JAN-C-768</td>
<td>May 1949</td>
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<td>Cupric Oxide</td>
<td>CuO</td>
<td>MIL-C-13600A</td>
<td>May 1962</td>
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<td>Dextrin, Technical</td>
<td>(C₄H₁₀O₅)ₓ</td>
<td>MIL-D-3994B</td>
<td>Aug 1970</td>
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<td>Diatomaceous Earth</td>
<td>Kieselguhr</td>
<td>MIL-D-20550B</td>
<td>Aug 1968</td>
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<td>Di-2-Ethylhexylphthalate</td>
<td>C₆H₄[COOCH₂CH(C₂H₅)C₄H₉]₂</td>
<td>MIL-D-13796A</td>
<td>May 1962</td>
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<td>Di-(2-Ethylhexyl) Sebacate</td>
<td>(C₄H₈COOC₆H₄)₂</td>
<td>MIL-D-10692</td>
<td>Nov 1952</td>
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<td>Dibutylphthalate, Technical</td>
<td>DBuPh</td>
<td>TT-D-301B</td>
<td>April 1960</td>
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<td>Diethylene Glycol</td>
<td>DEGc</td>
<td>MIL-D-23296A</td>
<td>June 1972</td>
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<td>JAN-D-242</td>
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<td>Diphenylamine, Technical</td>
<td>DPhA</td>
<td>MIL-D-98A</td>
<td>May 1962</td>
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<td>Dynamite, Commercial</td>
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<td>MIL-D-60365(1)</td>
<td>Nov 1968</td>
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<td>MIL-D-45413A(3)</td>
<td>Feb 1966</td>
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<td>Dynamite, NG, Gelatin</td>
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<td>MIL-D-28606</td>
<td>Aug 1972</td>
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<td>Ether, Diethyl, Technical</td>
<td>Eth</td>
<td>MIL-E-199A(1)</td>
<td>Dec 1966</td>
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<td>Ether, Petroleum, Technical</td>
<td>Petr eth</td>
<td>O-E-751B</td>
<td>April 1956</td>
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<td>Ethyl Alcohol (For Ordnance Use)</td>
<td>Alc</td>
<td>MIL-E-463B</td>
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<td>Ethyl Centralite (Carbamite)</td>
<td>EtCentr</td>
<td>MIL-E-255A(1)</td>
<td>June 1966</td>
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<td>Edylene Glycol, Technical</td>
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<td>MIL-E-9500A(2)</td>
<td>Dec 1972</td>
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<td>Explosive Composition A5</td>
<td>Comp A5</td>
<td>MIL-E-14970A(1)</td>
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<td>Explosive Composition HTA-3</td>
<td>HTA-3</td>
<td>MIL-E-46495A(1)</td>
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<td>Explosive Compositions, HBX Type</td>
<td>HBX</td>
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<td>May 1973</td>
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<td>Explosive, Plastic-Bonded Molding Powder (PBXN-5)</td>
<td>PBXN-5</td>
<td>MIL-E-81111A</td>
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<td>Graphite, Dry</td>
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<td>MIL-G-155A(2)</td>
<td>July 1967</td>
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<td>HMX (For 30mm Ammunition)</td>
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<td>Hydrazine Solution (22%)</td>
<td>H₂N₂H₂</td>
<td>MIL-H-22251</td>
<td>Nov 1959</td>
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<td>Hydrochloric Acid, Technical</td>
<td>HCl</td>
<td>O-H-765B</td>
<td>May 1969</td>
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<td>Incendiary Mixture PTI</td>
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<td>Aug 1950</td>
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<td>Iron Oxide, Black, Technical</td>
<td>Fe₃O₄</td>
<td>MIL-I-275B</td>
<td>May 1969</td>
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<td>Iron Oxide, Ferric, Red Dry (Natural and Synthetic)</td>
<td>Fe₂O₃</td>
<td>MIL-I-706A</td>
<td>Aug 1962</td>
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<td>Lactose, Technical</td>
<td>C₁₂H₂₂O₁₁.H₂O</td>
<td>MIL-L-13751A</td>
<td>May 1966</td>
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<td>Lead Azide</td>
<td>LA</td>
<td>MIL-L-3055A</td>
<td>Sept 1962</td>
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<td>Lead Azide RD-1333</td>
<td>LA RD-1333</td>
<td>MIL-L-46225C</td>
<td>Aug 1968</td>
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<td>Lead Azide, Special Purpose (For Use in Ammunition)</td>
<td>LA SP</td>
<td>MIL-L-14758</td>
<td>May 1968</td>
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<td>Lead Carbonate, Basic, Dry (For Ordnance Use)</td>
<td>2PbCO₃, Pb(OH)₂</td>
<td>MIL-L-18618(1)</td>
<td>April 1956</td>
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<td>Lead Chromate (For Use in Ammunition)</td>
<td>PbCrO₅</td>
<td>JAN-L-488</td>
<td>Aug 1947</td>
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<td>Lead Dioxide, Technical</td>
<td>PbO₂</td>
<td>MIL-L-376B(2)</td>
<td>Feb 1968</td>
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<td>Lead Mononitroresorcinic</td>
<td>LMNR</td>
<td>MIL-L-46496(1)</td>
<td>Aug 1962</td>
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<td>Lead Nitrate, Technical</td>
<td>Pb(NO₃)₂</td>
<td>MIL-L-20549A</td>
<td>Jan 1968</td>
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<td>Lead Steyrnate, Basic</td>
<td>basic-LSt</td>
<td>MIL-L-16355C</td>
<td>March 1961</td>
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<td>Lead Steyrnate, Normal</td>
<td>α-LSt</td>
<td>MIL-L-757A</td>
<td>Sept 1968</td>
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<td>Lead Thiocyanate</td>
<td>Pb(SCN)₂</td>
<td>MIL-L-65A</td>
<td>Feb 1968</td>
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<td>Lead-Antimony (For Use in Ammunition)</td>
<td>Pb-Sb</td>
<td>MIL-L-13283B</td>
<td>Aug 1970</td>
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<td>Lithium Chloride (For Use in Ammunition)</td>
<td>LiCl</td>
<td>MIL-L-14752</td>
<td>May 1968</td>
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<td>Magnesium Oxide, Calcined</td>
<td>MgO</td>
<td>MIL-M-14779(1)</td>
<td>April 1972</td>
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<td>Magnesium Powder (For Use in Ammunition)</td>
<td>Mg</td>
<td>MIL-M-382B</td>
<td>July 1970</td>
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<td>Magnesium Stearate (For Use in Ammunition)</td>
<td>Mg(C₁₈H₃₅O₂)₂</td>
<td>MIL-M-542A(2)</td>
<td>Jan 1973</td>
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<td>Magnesium-Aluminum Alloy, Powdered</td>
<td>Mg-Al</td>
<td>JAN-M-454(1)</td>
<td>Feb 1952</td>
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<td>MOX-2 Explosive</td>
<td>MOX-2</td>
<td>MIL-M-46263</td>
<td>Aug 1960</td>
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<td>Mercurous Chloride (For Ordnance Use)</td>
<td>HgCl</td>
<td>JAN-N-201(1)</td>
<td>Feb 1971</td>
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<td>Mercury Fulminate</td>
<td>MF</td>
<td>JAN-M-219</td>
<td>May 1945</td>
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<td>Methyl Centralite (For Use in Ammunition)</td>
<td>MeCentr</td>
<td>MIL-M-19719A</td>
<td>July 1960</td>
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<td>Nitric Acid, Technical</td>
<td>NA</td>
<td>O-N-350A</td>
<td>April 1968</td>
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<td>Nitroglycerin</td>
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<td>Feb 1962</td>
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<td>Nitroguanidine (Picrite)</td>
<td>NGu</td>
<td>MIL-N-60501C</td>
<td>Feb 1973</td>
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<td>Oxamide Explosive Composition</td>
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<td>June 1966</td>
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<td>Polyisobutylene (For Ordnance Use)</td>
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<td>MIL-P-13298A</td>
<td>Nov 1963</td>
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<td>Polyvinyl Acetate Aqueous Emulsion (For Use in Ammunition)</td>
<td>PVAAE</td>
<td>MIL-P-50855</td>
<td>March 1971</td>
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<tr>
<td>Polyvinyl Chloride (For Use in Pyrotechnics)</td>
<td>PVC</td>
<td>MIL-P-20307</td>
<td>Nov 1951</td>
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<td>Potassium Dinitrohydroxy Hydrobenzofuroxan (For Use in Ammunition)</td>
<td>KDNBF</td>
<td>MIL-P-50486</td>
<td>March 1971</td>
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<td>Potassium Nitrate</td>
<td>KN</td>
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<td>April 1956</td>
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<td>Potassium Perchlorate</td>
<td>KPer</td>
<td>JAN-P-217A(1)</td>
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<td>Potassium Picrate</td>
<td>KPic</td>
<td>MIL-P-10830</td>
<td>Jan 1951</td>
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<td>Potassium Sulfate (For Ordnance Use)</td>
<td>K$_2$SO$_4$</td>
<td>MIL-P-193A(1)</td>
<td>Aug 1965</td>
</tr>
<tr>
<td>Powder, Black</td>
<td>BkPr</td>
<td>MIL-P-223B(1)</td>
<td>July 1963</td>
</tr>
<tr>
<td>Powder, Black, Sodium Nitrate</td>
<td></td>
<td>JAN-P-362(1)</td>
<td>Dec 1946</td>
</tr>
<tr>
<td>Powder, Metal, Atomized (For Use in Ammunition)</td>
<td></td>
<td>MIL-P-14067B(3)</td>
<td>Nov 1971</td>
</tr>
<tr>
<td>Powder, Molding, PBX 9010</td>
<td>PBX 9010</td>
<td>MIL-P-45447</td>
<td>July 1960</td>
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<tr>
<td>Powder, Molding, PBX 9404</td>
<td>PBX 9404</td>
<td>MIL-P-45446A</td>
<td>Aug 1962</td>
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<tr>
<td>Powder, Photoflash</td>
<td></td>
<td>MIL-P-466A</td>
<td>April 1951</td>
</tr>
<tr>
<td>Powder, Propellant, Cordite N</td>
<td></td>
<td>MIL-P-17449(2)</td>
<td>May 1972</td>
</tr>
<tr>
<td>Powder, Propellant, AA (For 20mm gun)</td>
<td></td>
<td>MIL-P-17646(2)</td>
<td>May 1972</td>
</tr>
<tr>
<td>Powder, Propellant, M10</td>
<td></td>
<td>JAN-P-715</td>
<td>Jan 1949</td>
</tr>
<tr>
<td>Propellant, Double Base, Type N-2</td>
<td>JPN</td>
<td>MIL-P-18617</td>
<td>June 1955</td>
</tr>
<tr>
<td>Quinonedioxide (For Rocket Motor, 3.0 inch, Mark 32, Mod O)</td>
<td>HONC$_6$H$_4$NOH</td>
<td>MIL-Q-23703(1)</td>
<td>Feb 1965</td>
</tr>
<tr>
<td>RDX</td>
<td>RDX</td>
<td>MIL-R-398C(1)</td>
<td>Oct 1963</td>
</tr>
<tr>
<td>RDX, Desensitized</td>
<td></td>
<td>MIL-R-13742(1)</td>
<td>April 1972</td>
</tr>
<tr>
<td>Silicone Rubber, Foaming Compound (For Use in Ammunition)</td>
<td></td>
<td>MIL-S-50457</td>
<td>Jan 1970</td>
</tr>
<tr>
<td>Sodium Azide, Technical</td>
<td>SA</td>
<td>MIL-S-20552A</td>
<td>July 1962</td>
</tr>
<tr>
<td>Sodium Carboxymethyl Cellulose (For Use in Ammunition)</td>
<td>NaCMC</td>
<td>MIL-S-51132A</td>
<td>Sept 1964</td>
</tr>
<tr>
<td>Sodium Nitrate</td>
<td>SN</td>
<td>MIL-S-322C</td>
<td>Feb 1968</td>
</tr>
<tr>
<td>Material</td>
<td>Abbreviation or Formula</td>
<td>Specification</td>
<td>Date</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------</td>
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<td>--------------</td>
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<tr>
<td>Sodium Resinate, Technical</td>
<td>SRes</td>
<td>O-S-607C</td>
<td>March 1967</td>
</tr>
<tr>
<td>Sodium Sulfate, Anhydrous, Technical</td>
<td>SS</td>
<td>MIL-S-50004A</td>
<td>June 1968</td>
</tr>
<tr>
<td>(For Use in Ammunition)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Oxalate, Technical</td>
<td>SOx</td>
<td>JAN-S-210</td>
<td>May 1943</td>
</tr>
<tr>
<td>Strontium Nitrate, Anhydrous</td>
<td>Sr(NO₃)₂</td>
<td>MIL-S-20322B</td>
<td>April 1973</td>
</tr>
<tr>
<td>Strontium Oxalate</td>
<td>SrC₂O₃·H₂O</td>
<td>MIL-S-12210A</td>
<td>July 1956</td>
</tr>
<tr>
<td>Strontium Peroxide</td>
<td>SrO₂</td>
<td>MIL-S-612A</td>
<td>Sept 1964</td>
</tr>
<tr>
<td>Titanium Dioxide, Dry</td>
<td>TiO₂</td>
<td>MIL-T-48149</td>
<td>April 1973</td>
</tr>
<tr>
<td>Trichlorotrifluoroethane (For Use in Ammunition)</td>
<td>C₂Cl₆F₆ClF₂</td>
<td>MIL-T-14757</td>
<td>May 1968</td>
</tr>
<tr>
<td>Tungsten Powder (For Pyrotechnics)</td>
<td>W</td>
<td>MIL-T-48140</td>
<td>April 1972</td>
</tr>
<tr>
<td>Wax, Hydrocarbon (For Ordnance Use)</td>
<td></td>
<td>MIL-W-13945B</td>
<td>June 1968</td>
</tr>
<tr>
<td>Zinc Dust (For Use in Pyrotechnics)</td>
<td>Zn</td>
<td>MIL-Z-365A</td>
<td>March 1968</td>
</tr>
<tr>
<td>Zirconium (Granular and Powdered)</td>
<td>Zr</td>
<td>MIL-Z-399D(1)</td>
<td>April 1973</td>
</tr>
<tr>
<td>Zirconium-Nickel Alloy, Powdered</td>
<td>Zr-Ni</td>
<td>MIL-Z-11410B</td>
<td>Feb 1968</td>
</tr>
</tbody>
</table>

**NOTES:**
1) The above lists unclassified Federal, Military, and Departmental Specifications
2) Revisions are indicated by a suffix letter to the basic number
3) Amendments are indicated by a suffix number in parenthesis to the basic number
4) The date listed is that of the latest issue, revision or amendment as of December 1973
5) All requests for copies of Specifications should state title and identifying number. Requests should be submitted to: Commanding Officer
   Naval Publications & Forms Center
   5801 Tabor Avenue
   ATTN: NPFC
   Philadelphia, Pennsylvania 19120
6) Federal Specifications will not generally be furnished by the Naval Publications & Forms Center to commercial concerns unless required in connection with a bid or contract, or for sufficient other justification. These documents may be purchased from:
   Business Service Center
   General Services Administration
   Washington, DC 20405
Explosives, Color Identification by. See COLOR REACTIONS AND COLOR REAGENTS in Vol 3 of Encycl, pp C405-L to C420-L

Explosives, High Density. L. F. Audrieth & D. D. Sager in USP 2482089-091 (1949) & CA 44, 839 (1950) disclosed three tricomponent HE compounds for liquid loading into shells, bombs, etc. In the first patent Cyclotrimethyl- enetriminitramine is suspended in a solution of Trinitrotoluene-methylamines in TNT. In the second patent EDNA is suspended in a solution of the same two HE’s. In the third patent EDNA is suspended in a solution of PETN in TNT. In all cases solidification occurs after loading.

Explosives, Improvised. Improvised explosives are those usually made at the site from readily available oxidizers, fuels, binders and stabilizers. Some of them were cited during oral presentation by Dr. H. J. Matsuguma at Explosives Division, FRL, Picatinny Arsenal, Dover, N.J. No report was issued. [See also Explosives, R&D (Research & Development)]

Ref: O.E. Sheffield, Editor, Explos Div Newsletter, No 25, p 9 (July 1972)

Explosives, Introduction to. A booklet entitled: "Introduction to Explosives", Publication NBC 002, 86pp, 88 illustrations, can be obtained for $3.00 from the National Bomb Data Center, International Association of Chiefs of Police, 11 Firstfield Rd, Gaithersburg, Maryland 20760. Accdg to review given by G. Cohn, Ed, Expls & Pyrots 7(1), 1974, the booklet is written in simple terms that provide a general understanding of the nature of explosives & expls. Written to furnish a source of background to police, fire, and security officials, it can also serve students, management, or others who would benefit from having a brief, clear, general overview but do not need a textbook or technical manual.

Explosives Consumption. The apparent consumption of industrial explosives in the US for 1972 was 2670 million pounds (about 1210 million kilograms). Apparent consumption of explosives and blasting agents increased in all use categories except in construction and metal mining.

<table>
<thead>
<tr>
<th>Used In:</th>
<th>Consumption 1972</th>
<th>Change from 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Million lbs</td>
<td></td>
</tr>
<tr>
<td>Coal Mining</td>
<td>1213</td>
<td>+13.0</td>
</tr>
<tr>
<td>Quarrying and Non-metal Mining</td>
<td>494</td>
<td>+ 0.8</td>
</tr>
<tr>
<td>Railway and Other Construction</td>
<td>467</td>
<td>- 2.3</td>
</tr>
<tr>
<td>Metal Mining</td>
<td>431</td>
<td>- 5.8</td>
</tr>
<tr>
<td>Seismograph</td>
<td>19</td>
<td>+ 7.7</td>
</tr>
<tr>
<td>All Other</td>
<td>47</td>
<td>+17</td>
</tr>
</tbody>
</table>

The top-ranking states: Ky, Pa, Indiana, West Va, and Arizona, consumed 1170 million pounds or 44% of all explosives and blasting agents used.

Note: The apparent consumption of industrial explosives in the US for the 5 previous years is shown below for reference. Info is from surveys like Ref 1 but of earlier years.

<table>
<thead>
<tr>
<th>Used In:</th>
<th>Consumption in Million lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Mining</td>
<td>1071</td>
</tr>
<tr>
<td>Quarrying and Non-metal Mining</td>
<td>490</td>
</tr>
<tr>
<td>Railway and Other Construction</td>
<td>478</td>
</tr>
<tr>
<td>Metal Mining</td>
<td>457</td>
</tr>
<tr>
<td>Seismograph</td>
<td>17</td>
</tr>
<tr>
<td>All Other</td>
<td>40</td>
</tr>
</tbody>
</table>

2) G. Cohn, Ed, Expls & Pyrots 7(1), 1974

Explosives Containing Nitrocellulose. Nitrocellulose containing ignition mixtures are prevented from ignition by incorporating one or
more monohydric alcohols containing no more than six carbon atoms

Ref: W.D. Trevorrow, USP 2484131 (1949) & CA 44, 2247 (1950)

Explosives Containing Paraffin and Gasoline.
A compn useful as a propellant is derived from a mixture, with plasticized NC of dry potassium chlorate impregnated with Manila copal resin and of dry potassium chlorate/charcoal impregnated with a gasoline-paraffin distillate. Burning rate of the grains obtained by extrusion or sheeting/cutting is controlled by the amount of chlorate-resin present

Ref: S.J. McClung, USP 2483589 (1949) & CA 44, 2246 (1950)

Explosives RD, History of. All expls named by an RD designation originated in the Explosives Research and Development Establishment (ERDE) of the Ministry of Technology in Waltham Abbey, Essex, England. ERDE, actively engaged in R&D of expl formulations for many years, found early that it was not enough to label a compd merely by its chem formula. Form of the ingredients, method of manuf, as well as several other factors affect the final product. Thus RD 1333 Lead Azide (LA) is a very specific expl that differs significantly from other LA’s. Another example is a new form of dextrinated LA called RD 1352. Both expls are in the 1300 series, the block for primary expls.

Accdg to Dr John M. Jenkins, the ERDE’s most known expl, Cyclonite, does not have a number but was merely labeled with the letter X, making it RDX. Legend has it that years ago a researcher forgot the number of a particular kind of Cyclonite. The information was locked in a safe, probably for security reasons. But when an immediate designation was required, the researcher suggested calling it X. It is not guaranteed that this legend is true, but it is one version of the nomenclature of RDX

Ref: G. Cohn, Edit, Expls&Pyrots 7(1), 1974 (Review)

Explosives Sensitivity Data. Card-gap and projectile sensitivity data are presented by Watson (Ref 1) for a wide variety of expl comps tested at the USBurMines laboratories in more or less standard test geometries. The results of both tests are in good agreement in that they provide the same sensitivity ordering for different subclasses of expls. Least sensitive were homogeneous liquids that did not exhibit a tendency to undergo low-velocity detonation, AN-FO (Ammonium Nitrate-Fuel Oil), and most cast military expls. Of intermediate sensitivity were pressed and powdered military expls, cast Pentolite, permissible and nonpermissible water-based expls, and one commercial two-component expl. The most sensitive were permissible and nonpermissible Dynamites and expls susceptible to low-velocity detonations

2) G. Cohn, Edit, Expls&Pyrots 7(1), 1974 (Review)

Explosive Trains. An expl train is an assembly of elements arranged in order of decreasing sensitivity. The function of the train is to accomplish controlled augmentation of a small impulse into one of suitable energy to cause the main chge of the munition to function

Expl trains may be divided into two general classes: high explosive trains and low explosive trains, according to the type of expl used in the main chge. An expl train may also be designated accdg to the item in which it is assembled. The most common expl train is the fuze explosive train. If a bursting chge is added, it is commonly called bursting charge explosive train. An example of a low expl train is the propelling charge explosive train

Essential elements of a high expl train are:
a) a primary or low expl chge contained in a suitable housing
b) an intermediate chge of primary expl (most commonly Lead Azide) in which transition from burning to detonation takes place
c) a secondary high expl chge (RDX) that intensifies the shock output from the intermediate chge
d) a main change consisting of a secondary HE (TNT) that produces the desired effect

e) auxiliary elements for special purposes are leads & relays, delay or time elements, or a booster change

The effectiveness of one change in initiating another is determined by the props of the expl, its loading density, and the dimensions & confinement of the change. The effective output of a donor charge increases systematically with its diameter. The optimum diameter of an acceptor, from the point of view of the air gap across which it can be initiated, is slightly less than the diameter of the donor, especially for well confined columns of expls.

See also Section 9 "Physical Tests for Determining Explosive and Other Properties of Detonators, Primers, Igniters and Fuzes" in Vol 4 of Encycl, pp 1078ff

Refs: 1) Anon, "Ordinance Explosive Train Designers' Handbook", NOLTR 1111(1952), Chapters I & 2 2) Anon, "Explosive Trains", AMCP 706-179(1965), Chapters 1, 2 & 3

Explosivos de seguridad. Span permissible expls. One of such expls, known as Nitramita was manufd at the Fábrica de Granada. It contd AN 80 & TNT ("trilita" in Span) 20%. The Nitramita manufactured at the Fábrica de dinamita de Galdácano contd AN 88 & DNB, Naphthalene 12%

Refs: Vivas, Feigenspan & Ladreda 2(1946), 378

Explosivos de seguridad de la Fábrica de dinamita de Galdácano, listed on p 378 of Vivas, Feigenspan & Ladreda 2(1946) also listed in Vol 3 of Encycl, p C455-L, under Coal Mining Explosives, Permissible

Explosophore. See under Auxoexplose or Auxoplosopherophore; Explosophore or Plasphore in Vol 1 of Encycl, pp A513-R to A514-R

EXPLOTRON. A light generator designed to extract, for useful purposes, the brilliant flashes produced by explosives has been patented by De Ment (Refs 1-9). The device called an "expleton" takes an explm at short range and hitherto inaccessible ranges and plucks the pristine light from crushing blast, flying debris, and deadly nuclear radiation & radioactive material that may be present. The principles upon which the exploton is based are the enormous velocity difference between light (186000 miles/sec) and blast (several miles/sec) and the fact that light can be cleanly deflected in ways that blast cannot.

In essence, the exploton is a ducted structure optically coupled at one angle to a fragile optical member which is reflective to electromagnetic radiation and destructible by non-electromagnetic radiation. Upon actuation of the expl light source, the electromagnetic radiation is directed by a mirror to the irradiable target, and the slower non-electromagnetic radiation breaks the mirror and moves along the passage into a chamber where the blast & debris are diverted from the target.
There are three basic varieties of explo-tons: a) furcated or branched  b) recti-lineal or retroreflective and  c) hybrids of a & b and debris S break out FRO and sink into leg 4; PV & PV' may be side ducts for special gas loading, br vacuumization or for explosion plasma manipulation.

A branched or furcated explotron may be variously configured to increase the light-from-blast separation efficiency and to optimize the coupling of the reflected radiation with the irradiable target T. Fig 2 shows the "Y" Configuration Explotron. Both "T" & "Y" forms of the explotron are considered unitary or modules which can be expanded into zig-zig, blind-alley, and like forms. Each may be optoeexplosively and blast fluidically designed according to need.

The rectilineal or retroreflective explotron is simply a straight pipe or tunnel. At the upstream end there is sited the irradiable target T which, depending upon the power-

FIG 1
FURCATED OR "T" CONFIGURATION EXPLOTRON

A furcated explotron (Fig 1) consists of a main tube with at least one side-arm angularly conjoining the main tube. At one end of the main tube a light generating expl (optoeexplosive) is sited & fired. In Fig 1 the expl light source is contained within 1, the light generating leg is 2, LS is the light-shock admixture; light L first strikes the frangible reflective optic (FRO), fed off roll M into the juncture, and into the side arm 3 that is coupled with irradiable target T; slower-running shock & blast

FIG 2
ing of the system, the duct, ancillary venting means, type of optoexplosive light generator, and longitudinal profile, may or may not be hardened to take care of shock & pressure below the point of destruction by indirect explosion impact. Downstream from T is the optoexplosive energy source (male or female configuration, Figs not shown). The FRO (frangible reflective optic) is a plane, convex or concave mirror lens mounted 90° to the long axis of the system. The T may be either male or female to match the optical requirements. As with the furcated explotron, the rectilineal explotron may incorporate a variety of light-manipulating & kinetic energy-degrading components. These range from flux redistributors, to simple high albedo duct wall surfacings, to ablative and turbulencing vanes, to low-pressure venting pipes.

Hybridized or multimodal explotrons are combinations of the furcated & rectilineal types. Each type can be considered building blocks for more complex systems. The purpose of compounding the basic elements in each type of explotron is foremost the defeating of material energies, especially hot plasma close-in to a soft or semi-hardened target. Also, there is a range of choices of optoexplosive devices which, otherwise, emit inordinate arts of kinetic energy; and where pressure differentials are to be made within the system; or for speciality gas loadings, liquid loadings, or when parts of the system are extended into a body of water. In hybridizing a branched system, such as a T explotron (Fig 1), with a rectilineal one (Fig, not shown), the latter can be emplaced in the side-arm of the former. Between the angled frangible reflective optic (FRO) of the furcated explotron and the FRO of the rectilineal unit the target, T', is sited; the rear end of the T is hardened, and the face of the T receives the now upstream retro-reflected optoexplosion light.

There was also developed & patented by DeMent (Ref 10) a tellurian (underground) explotron for close-in treatment of an irradiable target by explosion-formed electro-magnetic energies characterized as reflectable off a frangible reflective optic such that the target is not overwhelmed by non-reflectable expln energies like blast & plasma. A typical tellurian explotron (shown in Fig 3) is a main duct horizontally sited below ground, optic (FRO) within one end of which is positioned and fired a mass of chemical or nuclear expl that generates electromagnetic & kinetic energies (black arrows). Junction midway or at any other convenient site along the main duct is at least one ductoid branch member, which rises to the ground surface and couples with the irradiable target. At the furcation of main duct & branch there is emplaced at a suitable angle a FRO, such as an aluminum foil mirror, which delivers the faster moving, non-reflectable radiation (white arrows) via the branch to the target. The slower-moving non-reflectable energies transit the main duct and break out the FRO and deposit in the ends of the main tunnel (small arrows).

Dr. DeMent tested the explotron by detonating a high explosive in an abandoned mine shaft on Fleming Island, Alaska in 1967 and succeeded in getting a 20-sq ft light beam off an Al foil mirror. Expls traditionally have been military & industrial "workhorses" because of their blast energy, but tremendous arts of light also are released by expls. This light energy is usually wasted and in most cases considered an undesirable product. Up to 80% of the energy of high-altitude nuclear expls can be released as wasteful radiant energy. Not all of the energy in an expl goes out as radiant energy but a chemical or nuclear expln can be optimized for best light output. Electrical energy often goes thru a series of heat-wasting steps before it becomes intense light.

There are many useful applications for clean explosion light. Several of these already have been explored with current light sources. Physics, chemistry, metallurgy, and life sciences use intense or special wavelength light for the irradiation of many objects from spacecraft to living tissue and
FIG 3
TELLURIAN (UNDERGROUND) EXPLotron
from the effects of sunlight in space to eye & brain surgery. Superintense light which appears to be neatly & efficiently extracted by the explotron could be employed for making new alloys, glasses, ceramics, and unusual high-temperature chemicals. It also might find application in the study of flash burn & diseased tissue research. DeMent does not restrict his projected applications to those requiring visible light. Depending on the selection of explns (chemical, electrical or nuclear) the wavelength spectrum can include soft X-ray, ultraviolet, visible, infrared, and even the transition region bordering microwaves. DeMent feels the explotron opens the door to a new technology of special devices that produce large ams of useful radiant energy.

See Refs for addnl details

**Exponents of a Polytropic Curve of Explosion Products of Condensed Explosives.** Accdg to Apin et al (Ref 1), the adiabatic curve of expl products at the front of a detonation wave may be described by the polytropic law: 
\[ p = A v^{-n} \]
where \( p \) = pressure, \( A \) = function of entropy, \( v \) = volume of expl products and \( n \) = polytropic exponent (See Ref 2, pp D290-R & D474-R). The exponent \( n \) (also designated as \( \gamma \)) depends mainly on the composition. The influence of temperature and pressure may be neglected. Experiments performed with expl compds and mixtures showed that over a wide range of temps and pressures of detonation, the exponent \( n \) of the polytropic curve of expl products may be obtd from the values of exponents of the individual products:

\[ n^{-1} = 2 \beta \n_f \]

where \( \beta \) = mole part of a given expl product and the values of \( n_f \) are the following: \( n_C^{\text{CH}_4}=1.9, n_N_2=3.7, n_\text{CO}_2=2.85, n_C=3.55, n_\text{CO}_2=4.5 \) and \( n_\text{N}_2=2.45 \) (Ref 1)

The work of Apin et al on calculation of exponents of a polytropic curve of expl products of condensed expls was summarized in Ref 2, pp D474-R & D475-L


**Expression** is the separation of liquid from a two-phase solid-liquid system by compression of the system under conditions that permit the liquid to escape, while the solid is retained between the compressing surfaces. Expression serves the same purpose as filtration but is distinguished from the latter in that the pressure is applied by movement of the retaining walls instead of pumping the material into a fixed space. Expression is usually employed to separate systems that are not easily pumped. It is also used instead of filtration when a more thorough removal of liquid from the cake is desired. The usual equipment for expression is a hydraulic press. Most of the common vegetable oils are produced by expression. In the expl in-
dusty, expression is used in the manufacture of propellants, namely during dehydration of a partly colloidal block of NC. This operation is described in Vol 3 of Encycl on p C399, under Colloiding Agents and Colloidal Propellants.


Exsudation. Fr for Exudation

Exsudation par étuvage. A French test described in Vol 1 of Encycl, p XI, under Exudation (or Sweating) Tests

Extending (Stretching or Lengthening) of Gelatin-Dynamites. Under this term are known Dynamites containing less than 20–25% NG–NC jelly and still able to be worked-up to a plastic mass which could be packed in the usual cartridge machines. Such expls were developed during WWI in Germany when a shortage of NG or of other "explosive oils" became acute. The extending (stretching) was achieved by replacing part of NG–NC jelly with aromatic nitrocompounds, miscible with NG–NC. Some aromatic hydrocarbons, such as naphthalene also could be incorporated. An oxidizing material as heavy as possible, such as K perchlorate, is of advantage in such Gelatin-Dynamites, in order to obtain high plasticity and high brittleness. In the case of stretched Dynamites which have a nearly complete combustion equation and acceptable fumes on expln, the above added substances do not act favorably on the permissibility, since the temperature of expln is raised considerably. In order to lower this temp, K chloride was incorporated in Germany.

When other European countries adopted extended Dynamites, they started to use NaCl in permissible expls, but in England they preferred to use Amm oxalate in their "permitted" expls.

Besides substances miscible with NG–NC, Germans used in some of their stretched Dynamites liquids insoluble in NG but capable, on being emulsified with it, of increasing the plasticity of the expl in the manner desired. One of such additives was developed at the Carbonitfabrik under the name of Malon. It was a jelly obtd by boiling glycerin with an aqueous soln of glue, for increasing the plasticity. The Dynamit AG, formerly Nobel & Co, incorporated a substance wholly or partly sol in water or which swelled up with it, such as dextrin, starch, potato flour or gums.

Also a pure glycerin and so-called Gum-Sugar (a syrupy concd sugar soln which would not crystallize) was used. The small amts of vegetable oils, or paraffin oil and the so-called concentrated waste sulfite liquor, patented in Germany after WWI, also were found suitable for stretching Gelatins.

In contrast to the above substances, which are carbonaceous materials and consequently require oxygen for their combustion, and raise the temp of expln, the Dynamit AG developed in 1919 the use of accurately measured quantities of said Ca nitrate soln, which is in itself an oxidizing agent. It imparts to the expl a high degree of plasticity without affecting the sensitiveness by the attendant water content. It allows the manuf of gelatinous expls of low NG content which cartridge will have an oxygen excess and high charge limits. These expls were known as Wetter-Nobelits.

Although extended or stretched Dynamites could be called Substitute Explosives (Ersatz sprengstoffe, in Ger), they should not be confused with Ersatz sprengstoffe of WWII listed in PATR 2510 (1958), pp Ger 43 & Ger 44 and also in Vol 5 of Encycl, p E122, Table E15.

In Vol 5 of Encycl under DYNAMITE AND SUBSTITUTES, pp D1584-L ff are also included expls which contain no NG, nor other
expl oil. Such substitute exs are AN-FO (Ammonium Nitrate-Fuel Oil)

Another example of Dynamite-type exs contg no NG are Nitrostarch Explosives developed at the Trojan Powder Co (now called Commercial Solvents-Trojan Powder at Allentown, Pa). See Vol 5, p D1605-L
Ref: Ph. Naoum, “Nitroglycerine and Nitroglycerine Explosives”, translated from German by E.M. Symmes, The Williams & Wilkins Co, Baltimore, Md (1928), pp 333, 405, 406 & 408

Extensometer for Testing High Explosive Materials. Proposed is a design for an extensometer to measure unit length changes upon compression or tension in ⅜ x 1-inch lengths of HE used for the instantaneous assembly of the component fissionable materials in nuclear devices. The length change sensors are resistance foil strain gages cemented to opposite sides of the center of a 12 x 375-mil cross-sectional area in the center of a piece of spring steel 20 x 750 x 1125-mil.
On the same side of the latter, at opposite ends, are soldered 1/8 x 1/2 x 1-inch brass blocks, each drilled to hold a pair of steel needles at 90° angle. Both gages are wired to one of the brass blocks and are connected to adjacent arms of a bridge for temperature compensation and to give a double signal output. A 3/4-inch coil tension spring attached to each block is used to clamp onto the specimen. The extensometer is calibrated by attaching to the dummy specimen of a Baldwin portable extensometer comparator which will cause and read extensions of as little as 10⁻⁵mil

Extent of Propagation of Detonation (or Explosion) and Tests. See “Ability to Propagate Detonation- Transmission of Detonation or Extent of Propagation of Explosion”, in Vol 1 of Encycl, p VII

More detailed discussion, with numerous refs, is given in Vol 4, pp D402-L to D417-R, under “Detonation (and Explosion), Initiation (Birth) and Propagation (Growth or Spread) in Explosive Substances” and on pp D497-L to D498-R under “Detonation (and Explosion), Propagation Through Explosive Charges”

Exterior (or External) Ballistics. See under “BALLISTICS” in Vol 2, pp B7-L to B8-L


Extinction (or Elimination) of Muzzle Flash.
See under Flash-Reducing Agents or Anti-flash Agents

Extinguishers for Inflammables. There has been patented a process for extinguishing fires, especially those of hydrocarbons (whether gelatinized or not). The process consists of using the action of an extinguishing agent, such as a chlorinated solvent & water, spread over the fire in the form of an emulsion. It can include separately or in combination, the following characteristics:

a) the emulsion of the two products is made at the time it is utilized by means of any type of mixing
b) emulsion is assured by the presence of an emulsifying product contained in the water or in the extinguishing agent, or from a combination of two substances contained one in water and the other in the extinguishing agent
c) the extinguishing agent is carbon tetrachloride
d) the proportion of the extinguishing agent in the emulsion is ca 20%
Ref: Dubrisay & Ficherolle, MP 38, 449-51 (1956) (FeP 1099973, 14 Sept 1955)

Extraction and Distribution or Partition.
Extraction is the act of transferring a material
from one or more liquid or solid phases in which it is dissolved or dispersed, to another phase which is liquid. Laboratory extractions are usually made in a Soxhlet or Wiley apparatus. One of the most important laws of extraction is the distribution (partition) law formulated by W. Nernst in 1891: "A solute dissolved in one phase in equilibrium with another, immiscible phase, will distribute itself between the two phases so that the ratio of the concentrations in the two phases is a constant at a fixed temperature." If $C_1$ and $C_2$ are concentrations in the lighter and heavier phase, respectively, then $C_1/C_2 = k$, where $k$ is the distribution constant, or the partition coefficient. It should be noted that this equation holds only for the simplest case, in which the molecules in each of the phases are in the same state of aggregation.

Extraction has long been used for preliminary separation of mixtures into groups. With present-day techniques, it can be further used to separate and quantitatively estimate the components of mixtures of closely related substances, such as members of a homogeneous series. The basis for the first purpose is frequently that of solubility or of widely differing partition ratios. As the purpose of the 1st method is the removal of one or several components of a system, the process may be called Extraction for Removal Purposes.

The basis for the second purpose is the use of a two-phase distribution in conjunction with a countercurrent process of some sort, so that separation may be made in spite of closely related partition ratios. This method may be called Extraction for Fractionation Purposes.

Extraction procedure is used extensively in Explosives Laboratories and Plants (See next item).


Scheibel, "Liquid-Solid Extraction" (17 refs)

Extractions Used in Explosives Laboratories and Plants. Many uses of extraction process are known, most of them dealing with liquid-solid extractions. There are, however, some liquid-liquid extractions, as, for example, extraction by ether of NB (Nitrobenzenes), as dissolved Nitrocompds of TNT in Spent or Waste Acids. The method described in detail in Ref 1, Chap 1, pp 21–22 (which is now out of print) is as follows: Shake the bottle with the acid contg NB vigorously to mix the contents and pour quickly 50.00g into a small tared Pyrex or porcelain dish. Transfer quantitatively the sample into about 200ml distilled water placed in 400-ml beaker, cooled in ice-water. Transfer the cold soln into a 500-ml separatory funnel and add 50ml of ether. Remove the funnel from the stand and hold the stopcock firmly with the right hand. Close the top of the funnel with a ground glass stopper and, while pressing against it with the palm of the left hand, slowly invert the funnel. Immediately after this, open the stopcock to allow the vapors of ether to escape. Close the stopcock and, while holding the funnel in inverted position, mix ether with acid by gently swirling the funnel. Then open the stopcock to allow the vapors of ether (but none of the liquid) to escape. Repeat the above operations 2–3 times and then invert the funnel to normal position. Allow to stand until two layers separate. Open the stopcock
and draw off the acid-water layer into the above 400-ml beaker. Allow a few drops of ether to enter the beaker to avoid leaving any acid in the funnel. Draw off the ether layer from the funnel into the above tared dish (previously dried) and allow the ether to evaporate. For a more complete extraction repeat all the above operations using another 50-ml portion and finally a 25-ml portion of ether. Weigh the residue in the dish after evaporation and calculate as follows:

\[
\text{%NB} = \frac{\text{Wt of Residue} \times 100}{\text{Wt of Sample}}
\]

In liquid-solid extractions, if the solid is powdery, ground or in small crystalline form, the simplest method is to pack the sample in a Gooch or sintered glass crucible inserted in the neck of vacuum flask and to treat the solid with several portions of an appropriate solvent (such as benzene, water, ether, xylene, etc.). Such method is described in Ref 2, p A164-R for laboratory separation of AN from TNT in Amatol. Instead of using the crucible, a centrifuge can be employed. Similar method can be used for removal of impurities from crude solid expls, such as of TNT. On a plant scale, a large Nutsch or centrifuge can be used. Dr I.A. Grageroff, together with G.D. Clift and B.T. Fedoroff purified in 1941 at the small plant near Penns Grove, New Jersey many tons of low-grade, exudable TNT, which was melted from WWII ammunition into wooden boxes to be stored for more than 20 years at the bottom of the Delaware river. This TNT was remelted, ground, packed into Nutschees and purified by extraction with xylene, the only solvent not in short supply at that time. The laboratory method of purification of this TNT, including the graining procedure, was described in detail in Ref 1, Chap VII, where Fig 19 on p 4 showed the funnel used in the laboratory. Many tons of Grade I TNT were produced from impure TNT by Dr Grageroff's method and shipped to Europe. This was at the time when no TNT plants existed in the US. When the supply of old TNT was exhausted, Dr Grageroff constructed a small plant at Glen Wilton, Virginia. This plant, constructed in summer of 1941, was about 6 months ahead of large Govt financed Ordnance Plants. The plant at Glen Wilton exploded in winter 1941-42 after it was acquired by the Hercules Powder Co.

A method similar to purification conducted at Penns Grove was used by Dr Grageroff at Keystone Ordnance Works, Meadville, Pa, but here instead of xylene, "Sellite" (aqueous soln of Na sulfite) was used for extraction of impurities.

If the material cannot be extracted rapidly, it is more advantageous to use devices called "extractors". For example, extraction of NC from Cordites can be done by using a modified Wiley extractor. The method is described in Ref 3, p C539-R & C540-L. Ether-extractable material can be removed from Blasting Explosives, including Dynamites, by means of a Wiley-Richardson extractor as described in Ref 4, p D1628. The same type of extractor can be used for removal of water and water-alcohol soluble constituents (Ref 4, p D1632), for acid-soluble constituents (Ref 4, p D1634-R), or carbon tetrachloride and in acetone soluble constituents (Ref 4, p D1637).

In every analysis of propellants an extraction must be performed. The latest description of the method used by the US Amen Forces is of 1971 (Ref 5). Roweg, Soxhlet or equivalent extractor must be used and as extracting solvent, diethyl ether or anhydrous methylene chloride. Proceed as follows: Transfer an accurately weighed sample of propell, about 5g, to the thimble of the extractor and add prescribed solvent to the tared extraction flask. Insert the open lower part of the extractor into the neck of the extraction flask and insert thru the upper opening of the extractor the bottom opening of the reflux condenser. Assemble the apparatus on the hot plate, and adjust the temperature so that the solvent drips from the condenser at the rate of 2-3 drops per second. Extract for a time which experience or preliminary work has shown to be adequate for the type of sample. It takes 3 to 20 hours and for Roweg extractor 2-3 times faster than for Soxhlet. In order to determine the completion of the extraction, allow part of the extract to drip
from the bottom of condenser into a small tared dish. Then weigh it and if no increase in wt is observed, test the residue colorimetrically. If no change in color is observed, stop extraction, disconnect the flask and evaporate the solvent, using a stream of dry air. Leave the flask overnight in a vacuum desiccator and then weigh it to the nearest 0.1mg. Return the flask to vacuum desiccator for an additional 2 hours and reweigh. If the 2nd wt is within 0.0025g of the 1st, use the lowest of these wts. If, however, the variation between wts is more than 0.0025g, redesiccate the flask to obtain a difference of less than 0.0025g

\[ \% \text{Extractables} = \frac{A - B}{W} \times 100 \]

where:

- \( A \) = wt of flask with residue, in g
- \( B \) = wt of empty flask, in g
- \( W \) = wt of sample corrected for total volatiles

\[ \% \text{Solvent Insolubles} = 100 - \% \text{Extractables} \]


**Extra Carbonit (Brit & Ger).** An older mining expl: NG 35, NC 0.3, K nitrate 25.5, Ba nitrate 4.0, Na nitrate 34.7 & Na carbonate 0.5%

Ref:s: 1) Barnett (1919), 194 2) PATR 2510(1958), p Ger 45

**Extra-Dynamite of Nobel (Swed).** It was patented in 1879 by Alfred Nobel and is actually Ammongelatine Dynamit. Its compn is given in Vol 1 of Encycl, p A295-R and in Vol 5 of Encycl, p D1604-L, under Class V Dynamites. Extra-Dynamites were also described in the following Refs

Ref:s: 1) Daniel (1902), 293 2) Naoum, NG (1928), 11 3) Davis (1943), 335 4) Cook (1958), 10

"Extra" Dynamites (Amer). A trademark registered in the US Patent Office, owned exclusively by E.I. duPont de Nemours & Co (Inc) for two series of high weight strength, variable density Ammonia Dynamites. These Dynamites are NG sensitized AN Explosives with a constant weight strength of approx 65% throughout the series. In 1966 there were 8 Grades in High-Velocity and 7 Grades in Low-Velocity. A more detailed description of their properties, without revealing their compositions is given in Refs 1 & 2

Ref:s: 1) Blasters' Hdb (1966), 34-6 and Tables 4-1 & 4-2 2) Encycl of Expls, PATR 2700, Vol 5(1972), p D1604-L

"Extra" Dynamites "Red Cross" of DuPont & Co. They are NG-sensitized Ammonia Dynamites of 20 to 60% grade strengths and a uniform density of 110, 1½ x 8-inch, cartridges per 50 pounds. More detailed description of their properties without revealing their compositions is given in Ref

Ref: Blasters’ Hdb (1966), pp 33-4 and in Table 4-1

**Extralite.** Cundill (Ref 1) gives composition in parts: Zn chloride 50, AN 50, solid hydrocarbons 10, liquid hydrocarbons 5 & Amm carbonate 5. In Daniel (Ref 2) its compn is given in percentages as: Zn chloride 41.37, AN 41.97, solid hydrocarbons 4.16, liquid hydrocarbons 8.34 & Amm carbonate 4.16%

Ref:s: 1) Cundill (1889) in its French translation, MP 5, 333(1892) 2) Daniel (1902), 294

**Extraneous Electricity, Hazards of.** See ELECTRICITY, EXTRANEOUS AND HAZARDS ASSOCIATED WITH IT in Vol 5 of Encycl, pp E35-R to E55-L
**Extra Powder.** A variety of Giant Powder: NG 40, Na & K nitrates 40, resin 6, sulfur 6 & kieselguhr 8%, from which it differs by containing AN coated with vaseline. 
*Ref:* Daniel (1902), 293 (Extra Powd: t) & 324 [Géante(Poudre)].

**Extruders** are devices for loading by extrusion (qv) metals, plastics, expts and pyrotechnic compositions. For example, expts such as some Amatols, Explosive D, Compositions A & C, etc which cannot be cast-loaded can be loaded by pressing them thru a steel tube by means of a worm screw working inside. An extruder resembles devices used for loading Gelatin Dynamites in paper cartridges. Such devices are known as "sausage machines". An improved type is shown in Ref 1, p 306, reproduced here as Fig 4.

![Fig 4 IMPROVED SAUSAGE MACHINE](image)

Another type of extruding press is the so-called "macaroni press", used for making strands of smokeless propellants. Its use is described under "Extrusion" (Fig 5).

An extrusion press used in the manufacture of fuel binder composite propellants for use in US aircraft jatos is shown in Fig 6.

Mixing of the crystalline ingredients of oxidant, fuel & elastomer binder (butadiene-2-methyl-5-vinyl-pyridine copolymer plasticized with the formal of diethylene glycol monobutyl ether) 26% by vol is done in a sigma blade mixer. The completed mix is blocked in a hydraulic press to form a chge suitable for extrusion. The extruded strand is cut into grain blanks which are cured at elevated temp to complete the polymerization process. The cured blanks are then finished to final dimensions (Ref 3).

Addnl extruders for other applications are described in Ref 2. See also Extrusion which follows:
*Refs:* 1) Naoum, NG (1928), 306 (Fig 33)  
2) Perry (1963), pp 19-35  

**Extrusion of Metals, Plastics, Explosives and Propellants.** Extrusion is the process of forcing (by using pressure) a material in softened (plastic) condition thru a suitable orifice in order to produce a body of uniform desired cross-section, continuously. In order to render the material plastic, it is either preheated (as in the case of plastics, solventless smokeless propellant and some metals) or softened by adding a plasticizer (as in the case of some plastics and smokeless propellant). Extrusion may be considered as one of the branches of size adjustment.

Materials which are usually extruded include: some soft metals (lead, tin, copper, brass, aluminum, magnesium and various alloys); rubber, soaps, ceramics, foods, plastics, Dynamites, Explosives (like Amatol or Explosive D), and Smokeless Propellants. Most of the literature on extrusion is found in books on plastics.

For extrusion of conventional American Smokeless Propellants, the gelatinized mass of NC, blended with other ingredients, is charged into the so-called macaroni press, from which it is extruded thru a series of finely perforated plates. The pressure, supplied by means of a hydraulic ram, is between 2500 and 3800psi. This operation removes any solid foreign matter and aids the coagulating action of the solvent by further mixing and kneading. The material comes from the press in strands having the appearance of macaroni. The strands are allowed to fall into the final blocking press where the material is compressed hydraulically at about 3500psi into a solid block. This operation
FIG 5  MACARONI and BLOCKING PRESSES
 FIG 6  EXTRUSION PRESS

completes the colloid of the NC, and the material at this point is free from lumps of uncolloidal NC and is of uniform appearance.

The final block is placed into a graining press (finishing press) which may be either horizontal or vertical and from which it is extruded at pressures of from 2500 to 3800 psi that is fashioned to give the proper cross-section to the grains. The extruded material takes the form of flexible cylindrical cords with one or seven perforations. The press head may be equipped with one or more dies, depending upon the capacity of the press. When small arms propellant is being grained, there may be 36 strands issuing simultaneously from the head. However, with large caliber propellant, such as for 16-inch gun, it is customary to use but one die in the head. Water is run around the die to cool it during the operation. The propellant issuing from the press is either led over pulleys directly to a cutter, or allowed to coi up in a basket from which it is fed to the cutter. The latter is equipped with revolving knives which cut the propellant cord into the desired lengths, as it is fed against the knives by means of feed rolls.

Brunswig (Ref 1) & Stettbacher (Ref 2) describe European methods of extrusion of cannon and small arms smokeless propellants. A booklet issued by CALTEC (Ref 3) gives a brief description of the extrusion of Rocket Propellants. Until WWII, only solvent propellants were
Exudation in Explosives. (Exudation in Fr; Ausschuwitzung in Ger). Exudation is the act of sweating out liquid ingredients from an expl or explosion thru the pores of the solid components. This phenomenon is usually observed in Dynamites (especially those contg large percentage of “explosive oils”, such as NG (Nitroglycerin) and NGc (Nitro-glycol) or in impure aromatic nitrohydro-carbons, such as Grade II TNT (Setting Point 80.2°) used for loading shells during WWI.

In the case of Straight Dynamites, the liquid is held by capillarity or adsorption by the solids, such as wood pulp, sodium nitrate, etc. These expls are the most liable to exude.

In the case of Gelatin Dynamites, the liquid is held mainly thru the formation of a colloid and these do not exude unless they are subjected to high pressures or temperatures. However, if gelatins contain an insufficient amount of NC, or if the NC is of unsuitable character (too high nitrogen content, for instance), some liquid which is not a part of a colloid can be squeezed out by applying moderate pressures or temperatures slightly above room temperature. Some blasting gelatin require so little pressure to deprive them of part of their NG, that the pressure caused by weight of the cartridge in the box is sufficient to cause exudation.

Exudation is very undesirable from the point of view of safety because free NG or NGc is much more sensitive than Dynamite. Moreover, the loss of NG or NGc by exudation diminishes the strength of Dynamites, as well as their sensitiveness to detonation.

It is the general rule in the US that all Dynamites showing exudation are destroyed at once and that any surface with which the exuding liquid has come in contact is chemically cleansed or destroyed as a dangerous article.

Exudation in Shells Loaded with Grade II TNT and Amatol. Shortly after WWI, when large amounts of TNT and Amatol-loaded shells were stored, it was noticed that the TNT and 50/50 Amatol-loaded shells seemed
to be undergoing some sort of deterioration, evidenced by the exudation of black, oily, tarry material and, in some cases, a gas.

Investigation showed that the principal causes of exudation were:
1) The presence of impurities in the TNT
2) The use of alcohol shellac in the booster cavity, and alcohol for cleaning the threads in the nose of the shell
3) In the case of Amatol shells, the introduction of impurities contained in the technical Ammonium Nitrate (AN)

The principal impurities in item (1) were the undesirable isomers of TNT & DNT; their presence lowered the mp (Setting Point) of α-TNT from 80.75° to 80.2° (Specification grade) and could lower it much more. On casting TNT in the shell, the outside of the cast solidified first because of the cooling effect produced by the metal walls of the shell, while the center portion of the cast solidified last, because it was somewhat insulated. As the result of this cooling, the mixture that solidified at the outside contained a large proportion of high melting components, while the portion that solidified in the center core contained the bulk of the impurities because they solidified at a lower temperature. If such shells were stored at elevated temperatures in tropical countries or in the deep South of the United States, the low melting point areas would liquify and, due to expansion, force their way out thru the threads of the booster cup.

All this was purely physical action and no chemical reaction took place and no gas evolved, unless alcohol had been used. When alcohol was used, as in shellac for the booster cavity or for washing the threads, in the nose of the shell, some chemical reaction took place and not only exudate was formed but gas as well. This gas has proved to be Ethyl Nitrite. By laboratory experiments, it was determined that TNT and alcohol do react and give the same gas and tarry material as that found in the shells.

As a remedy, it is advisable to use TNT of a higher setting point than 80.2° and to use no alcohol.

Regarding the exudation due to impurities introduced by technical AN in TNT mixtures, it should be noted that this problem existed when AN was prep'd from ammonia obtained in the destructive distillation of coal. This AN contained many organic impurities (such as pyridine) which have been found to act in a manner similar to alcohol.

It was noted that 50/50 Amatol using impure AN, exuded, while 80/20 Amatol (AN 80 & TNT 20%) seldom did. This was because of the comparatively small amount of TNT present and because the AN absorbed most of the exudate. With the introduction of AN prep'd from synthetic ammonia (as was done during WWII) and the use of better grade TNT, the exudation of Amatols nearly stopped.

In addition to the black tarry exudate, some samples of TNT and Amatol contained the red particles of an expl compound which contained iron. It was shown that this material was the result of reaction of TNT and alcohol in the presence of iron. The iron came from corrosion of the shell by the exudate, in the case of TNT, or by moisture in the AN. Several methods were introduced to prevent rusting of the shell, one of them by coating the inside of the shell with acid-proof paint, another by controlling the moisture in the AN and still another by pouring on top of the Amatol some TNT as a "booster-surround". The purpose of the latter was to seal the hygroscopic AN from moisture.

Exudation is very undesirable because it is a fire hazard, causes corrosion of the shell and also causes cavitation in the charge.

It is a fire hazard because, when the exudate collects on the floor of a storage magazine, it might accidentally catch fire, especially if it contains red particles of the expl iron salt.

Corrosion of the shell case & booster cup is caused because the exudate is often acid in reaction. When exudation is noticed in any shell, the booster should be removed and the cavity cleaned.

Cavitation in the filler often resulted from exudation. It could cause trouble in two ways: first, by desensitizing the booster or the surrounding charge and, second, by
lowering the density of the loading, thereby decreasing the efficiency of the shell. Although the exudate contains TNT, it is much less sensitive to detonation, so that the booster is less liable to cause a high order detonation when initiated by a standard fuze, such as the Mark III. This can be remedied, however, by using the so-called "Horse Detonator" (qv).

It was assumed at one time that cavitation was dangerous since, during set-back, a premature might occur because of the crushing of one piece of TNT against another, or against the shell wall, or the pinching of TNT exudate in the booster threads. Investigations, conducted with 75 and 155mm shells which were in a very bad state of deterioration from exudation, showed that, even if these shells were fired at 12% excess pressure in the gun to make the worst possible combination of conditions, no premature resulted either in the gun or along the trajectory. It was, therefore, concluded that with those two caliber guns, it was safe to use exuding shell. The restriction in use of such shells was therefore removed.

Post-WWII investigations conducted at Picatinny Arsenal showed that a dark reddish-brown exudate collected from 105mm shells loaded with TNT consisted principally of a mixture of α-TNT with some β- and γ-TNT and, sometimes, traces of 2,4-DNT and other products of nitration of impurities in toluene. It is also probable that alcohol present in "NRC" sealing compound and/or other extraneous material might favor exudation.

The exudate had a much lower stability and bisance than α-TNT but the same sensitivity to friction or impact. In some of the 105mm shells as much as 39.5g of exudate was collected, which amounts to 1.8% of total TNT present (Ref 5).


Exudation Tests in Dynamites. Several tests are known. They were designed to determine whether Dynamites would remain unchanged in their composition under adverse conditions of storage.

The earliest description of exudation tests at our disposal is in the book of Daniel (Ref 1) in which are described the following tests:

a) British Government Test (probably obsolete) consisting of freezing and melting a weighed cartridge, repeated 3 times. No exudation should take place (Ref 1, p 292)

b) British Government Test, described in Daniel as Liquéfaction (Essai à) (p 409), was intended to determine exudation or softening of gelatinous expls stored at temperatures in hold of a ship. As such expls do not respond to Centrifuge Test, it is known that if not properly made they show exudation. This may be due to liquefaction of a portion of the gel and not merely to separation of NG from the NC and other components of the dope. A Gelatin Dynamite in this condition is unsafe to use. The test prescribed by HM Inspectors (Ref 1, p 37) was as follows: After stripping the wrapper from the cartridge of expl selected for the test, a section equal in length to its diam is cut transversely so that the ends are flat and the edges sharp. This is then pinned with its axis vertical to a flat wooden or cardboard surface and placed in an oven maintained at temp 85° to 90°F (29.4° to 32.4°C). After exposure of 144 consecutive hours (6 days and nights), the sample is removed and examined. It passes the test if the upper surface
is still flat with the edges still sharp and the diminution of height did not exceed 25%. Same test is described in Marshall (Ref 3) and Barnett (Ref 4).  
c) Another test, described by Daniel (p 293), was intended to determine exudation under moderate pressure, which is encountered during loading of Dynamites into cartridges. For this test a brass tube of the same diameter as cartridges was used. The tube was pierced with many tiny perforations and closed at the bottom. Thru its open top end, a cartridge was inserted all the way to the bottom and on top of it was placed a piston of a press which could develop pressures of 4-5 kg/sq cm. If no exuded liquid appeared around the perforations, the Dynamite was considered to pass the test.  

Note: It seems that the test could be made quantitative if the tube were wrapped, prior to the test, with one layer of tared filter paper. Then, if the paper were weighed after the test, exudate could be calculated.

A more recent French test called "Exudation par étrouage" is described by Ménard (Ref 6) and in Vol 1 of Encycl., p XI. A similar French test was described by Pepin Lehalleur (Ref 5, p 61) who also described the Pressure Test similar to that described in Daniel and the Centrifuge Test similar to that described in Refs 2 & 3 and in Vol 2 of Encycl., pp CI43-R & CI44-L.

Snelling & Storm (Ref 2, pp 8-11) described the following tests, used at that time (1916) at the USBurMines: a) Forty Degree Test  b) Pressure Test and c) Centrifugal Test. Then the Pressure Test was abandoned and in Bulletin 346 of 1931 (Ref 4, pp 25-6), only Centrifuge Test and Forty-Degree Test are described, in add'n to the British Test (pp 26-7). Centrifuge Test is described in Vol 2 of Encycl., pp CI43-R & CI44-L, while Forty-Degree Test is in this Vol. The British Test is described as item b under tests described in Daniel (Ref 1, p 409).


Exudation Tests for TNT and Amotols. The following test, called Ausschwitzungsprobe, was used in Germany during WWII: A 20-g sample of TNT, melted and cast as cylinder 18 mm in diam, was placed with the flat bottom part on a sheet of special Schleicher & Schüll filter paper resting on an aluminum plate. As a reference "standard", a similar pellet of Grade A TNT (setting point 80.6°F) was placed on the same sheet but about 100 mm away. The ensemble was placed in an oven and left there for 6 hours at 72°. After cooling, the diameter of the circle produced by exudate was measured and, if it were not larger than 35 mm, the TNT was considered as Grade A. Any diam between 35 and 70 mm was considered as Grade B (sp 79.5°). In addition to these two grades, the Germans manufactured Grade UK (Umkrystalliziert=recrystallized) with a sp of 80.7° to 80.8° (Refs 1, 2 & 4).

Sheffield (Ref 3) used the following test during his investigation of exudation of TNT in 105mm artillery shells conducted at Picatinny Arsenal after WWII: A portion of TNT was melted and cast in the form of discs about 1 cm thick and 5 mm in diam. After removing the rough spots, the disc was weighed and placed on 2-3 layers of hard, previously weighed, filter paper located in a flat aluminum dish (such as used for determination of moisture in NC), provided with a cover. After hearing the ensemble at 71°C (160°F)
for 16 hours, the disc was separated from paper while still at 71°, then cooled and re-weighed. The same was done with filter papers and, in addition, the diam of exudate spot was measured.

A summary of the pertinent results from exudation studies conducted at PicArsn was prep'd by Stein (Ref 5). In one series of tests to induce exudation and to obtain exudate samples for analysis and examination of properties, a loaded unfuzed shell was placed in an inverted position over a tared dish and maintained for several hours at 160°F (71°C), until exudation stopped. Then the dish was reweighed and % of exudate caled.


Exudation in Cast Explosives in Presence of Crack-Preventing Additives. See under "Anticracking Additives to Cast Explosives" in Vol 1, pp A461-R to A462-R

Eye Bombs (US Navy). The US Navy has under development or production what it calls its "Eye" series of bombs. The Snakeye is a 250 to 500 low drag bomb. (See Vol 4, this Encycl, pp D940-R & D941-L). The Rockeye is a new cluster bomb which can contain either anti-personnel or antitank bomblets. The Fireye is a new incendiary bomb and the Sadeye is another cluster bomb designed to be air-launched. It contains a large number of bomblets. The Weteye is a new chemical bomb of the non-lethal variety designed to replace the Navy MK 94.


Eyring Absolute Reaction Rate Theory. See "Absolute Rate Theory" in Vol 1 of Encycl, p A4-R and in Cook (1958), p 134

Eyring Detonation Theory. See "Detonation, Curved Front Theory of Eyring et al" in Vol 4 of Encycl, pp D242-R to D244-L
"F". Force or energy of expls, which is also called "specific pressure" (in French, force spécifique). "F" is the pressure (in atm) per unit area (cm²) that would be obtained by the expln of unit weight (1 g) in unit volume (1 cc), if the ordinary gas laws were applicable at that density.

Following is the formula, according to Abel:

\[
f = \frac{p}{C} \cdot \frac{V_0Q}{273} + \frac{p_0V_0T_1}{273} = \frac{Q}{C+T_1} \frac{p_0}{273} \text{ atm}
\]

where:

- \( p \) = pressure of expln in atmospheres
- \( v \) = volume of vessel in which expln takes place
- \( V_0 \) = specific volume of the gaseous products (volume of gases developed on expln) of unit wt of expl (calculated at 0° and standard pressure \( p_0 \)), expressed in cc/g
- \( Q \) = quantity of heat set free by the expln of unit weight
- \( C \) = sum of mean specific heats of the products of expln, expressed cal/g
- \( T_1 \) = absolute temperature of the expln before it is fired, which may be considered equal to 273°

In order to obtain \( f \) expressed in kg/cm², the above value has to be multiplied by 1.0333.

On substituting in the above formula, the value \( Q/C \) by \( t \) = maximum temperature of expln, and \( T_1 \) by 273°

\[
f = \frac{p_0V_0}{273} \cdot \frac{t + 273}{273} \text{ atm}
\]

According to the kinetic theory of gases, the kinetic energy of the expl gases is equal to 1.5f.

Berthelot used the expression \( V_0Q/C \), which he called "characteristic product" (Refs 3 & 4) to measure the power of the expl., but due to the difficulties of determination of \( C \), the product \( V_0Q \) has often been used instead. However, both of these expressions are unsuitable for expressing the power of expls, as can be seen from some comparative values given on p B105-R of Ref 4. However, this does not prove conclusively that the above expressions are without practical significance.


"F" (Dynamite). See Dynamit "F" (Swiss) in Vol 3 of Encycl, p C443-L, under "Swiss Commercial Explosives of Non-permissible Type".

F (Propellants). British Cordite type proplants of various compositions:
a) F/478/138/K: NC (wood) 56.0, NG 43.0, Centr 1.0, K cryolite 2.0, and C black 0.1 (added). FL (qv) 11 (PA) considered low: comp to LA or NG although this prop is not considered dangerous to handle.
b) F/488/343: NC 53.0, NG 43.5, Centr 1.5, DBuPh 2.0, C black 0.1, and wax 0.075 (added). FL 27. Both proplnts burned w/o deton.
c) F/547/18: NC 46.0, NG 23.0, acetylcellulose 12.0, triacetin 18.0, K cryolite 1.0, chalk 0.2, and wax 0.075 (added). This prop not ignites on impact.

Ref: P.W.J. Moore & R. Pape, BRDE Tech Mem No 14/M/54(3)(1954)

"F" (Propellants). Additional List of British post-WWII propellants:

F/428/180. A Brit prop with Adiabatic Flame Temperature (AFT) 1950°K: NC 65, NG 15.4, Carbamite (EtCentr) 2 & DBuPh (Dibutylphthalate) 17.5%

F/487/46. Ditto with AFT 1950°K: NC 20, Picrite (Nitroguanidine) (NGu) 60, DEGDN 11.16, EtCentr 2.64 & DBuPh 6.2%

F/487/68. Ditto with AFT 1950°K: NC 70, DEGDN 14.3, EtCentr 2 & DBuPh 13.7%

F/488/312. Ditto with AFT 2800°K: NC 56.5, NG 33, EtCentr 3.5 & DBuPh 7%

E551/66. Ditto with AFT 2800°K: NC 21, NGu 55, NG 21 & EtCentr 3%

F1. An Australian submachine gun characterized by a keen balance, facility of operation and lack of recoil. It is blowback-operated and fires the 9-mm Parabellum cartridge at a cyclic rate of about 650 shots per minute. The 8½-inch barrel delivers a muzzle velocity of about 1250 feet per second, using ammunition compatible with the Browning High Power Australian Service Pistol.

The F1 is manufactured at Lithgow Arsenal, Lithgow, New South Wales and is issued to AMF (Australian Military Forces) to complement the semiautomatic SLR (Self-Loading Rifle).

Ref: T.L. Golden, Ordn 57, 228-30 (Nov-Dec 1972)

F33B. Gasless incendiary mixture: Zr (200 mesh) 41.0, Fe₃O₄ (pigment grade, red) 49.0 & "Superfloss" 10%

Note: Superfloss is a trade mark of Johns-Manville Products Corp, NY for a grade of "Celite" (diatomaceous earth).

Ref: Tech Command, Army Chem Center, Maryland, "Development of an Incendiary Pellet", TCR-59 (May 1950)

FA-878. Frankford Arsenal primer composition consisting of Ba nitrate 20, Pb dioxide 20, granulated Zr 32.5, powdered Zr 7.5 & PETN (grade B) 20%. This mix is used in small arms cartridges.

Ref: Frankford Arsenal, "Primer, Pyrotechnics and Incendiary Compositions for Small Arms", Rev 2 (1954), p 43

Fabric Cordeau. A detonating fuse made from tubes or woven fabric filled with NC, TNT, PETN, etc. See Cord, Detonating in Vol 3, p C529-R and under Detonating Cords in Vol 3 p D103-R


Factors Influencing Velocity and Other Properties of Explosives. See Vol 4, p D3:7-L, under "Detonation, Factors Influencing Velocity and Other Properties of Explosives in"


Fading or Fadeout of Detonation. See Vol 4, p D223-R, under Detonation: Attenuation, Break, Cessation, Cutoff, Dying-out, Extinction, Fadeout and Failure

Fading of Detonation in Cones of Explosive. A deton wave once formed in an expl has a tendency to die out or "fade" if the diam of the expl is below a certain min (called boundary diam). It may be dted by using a cast cone detonated from the base. The diam of the cone at which the wave is extinguished is a measure of the fading properties of the expl. The observation may be made photographically by means of a rotating mirror camera. The value so obt txt tends to be less than the value from cylindrical columns of expl. See Vol 4, p D223

Ref: D.W. Woodhead & R. Wilson, Nature 167, 565 (1951)

Fading of Detonation in Solid Explosives was discussed by O.A. Gurton in ProcRoySoc 204A, 31-2 (1950) & CA 45, 10585 (1951)
FAE and FAX (Fuel-Air-Explosives). The acronym of the US Fuel-Air Explosives Program which has been changed from FAX to FAE to prevent confusion with Fighter-Aircraft Experimental (FAX) Program. FAE represents the entire fuel-air explosives program, including current projects.

Some basic work on the formation of spherical detonation waves from exploding gas mixtures confined in balloons was reported by Freiwald & Uhde (Ref 2). Magram in the US earlier studied the effects of expl gases (Ref 1). Many of the first feasibility studies of FAE and FAE weaponization developments were carried out at the US Naval Ordnance Test Station, China Lake, Calif (Refs 3 & 4).

Explosive vapor clouds were once considered a way-out technique. A cloud of volatile fuel, mixed with air, is discharged and then detonated on a target, with the same violent explosion that characterized grain-silo dust explosion or blast, when a propane tank truck blows up. This kind of explosion can level a city block. Very significantly for military purposes, it can reach around corners and into structures & shelters, which ordinary HE, fragmentation bombs and shells cannot do (Ref 12).

Fuel in gaseous, liquid or solid phase can be made to detonate in air (Refs 5, 6 & 7). These detonations produce much lower maximum pressures (order of 20 atmospheres) than detonation of high explosives, but can produce larger static and dynamic impulses (defined by \[ \int P \, dt \] and \[ \int \frac{1}{2} \rho \dot{U}^2 \, dt \])

where: \( P \) = pressure  
\( t \) = time  
\( \rho \) = density  
\( U \) = velocity

at a fixed position). per weight of fuel and can cause blast effects over larger areas. Essentially this is a consequence of the high energy of explosion per unit weight of fuel (when reacted with atmospheric oxygen) compared to high explosives.

More recent development has centered on detonation of liquid fuel drops dispersed in air, although fuel films will also support detonation (Ref 9). In the fuel drop-air explosive, it is necessary that relatively large liquid fuel drops be broken up into a micro-mist of fuel spray. The fuel spray can then combust rapidly enough to drive the detonation shock. Drop breakup is accomplished by the high speed gas jet associated with the detonation shock. Since breakup is a relatively slow process, the reaction zone of these detonations is large. Losses from this reaction zone can cause the detonation velocity to be less than the theoretical Chapman-Jouguet velocity, with the velocity proportionally lower for larger drop diameters (Ref 8). Both drop size and drop spatial distribution (that is local fuel-air ratio) have important effects on these detonations.

Monopropellant drops have been shown to be capable of detonating in a manner similar to liquid hydrocarbon fuels (Ref 11). With monopropellant explosives, energy release per unit volume of explosive is not limited by atmospheric oxygen; however, energy release per unit weight is smaller than for fuels using atmospheric oxygen.

FAE have joined chemical & nuclear expls for military use. Vaporized fuel from air-dropped or preplaced canisters, exploded on a target produces highly destructive blast. In Vietnam, FAE cleared out mine fields & booby traps, and opened up helicopter landing fields (Ref 15).

Continued development of high-speed FAE weapons systems now depends on a joint service proposal. The joint service plan identifies funding & specific areas of development. The first bombs developed by the US Navy, CBU-55, were used in Vietnam, and tests to perfect an advanced version of the weapons system have continued. The CBU-55B air-to-surface free-fall cluster bombs were developed for helicopter and slow-speed fixed-wing aircraft delivery to clear helicopter landing zones of mines & booby traps. This FAE bomb was designed to disperse a mix of vaporized fuel (ethylene oxide, propylene oxide, methylacetylene/propane and others) in a cloud 50 ft in diam and approx 8 ft thick. It has three 100-lb individual canisters 13.6 inches in diam by 21 inches long, each containing ca 72 lbs of fuel. The canisters separate from the dispensers after
release from an aircraft, and each is individually retarded by a drogue chute as it nears the target (Ref 13)

The Air Force at its Armament Development & Test Center, Eglin AFB, Florida and the Navy at the Naval Weapons Center, China Lake, Calif have been working separately to perfect a second-generation FAE weapons system as a bomb for high-performance jet aircraft delivery. The Army, meanwhile, has been involved in developing its own FAE system centered on mine clearance. To assess the terminal effects of the Navy FAE 2 weapon, this second-generation system was placed on a barge and floated near the decommissioned destroyer escort, USS McNeil, anchored off San Clemente Island, Calif in 90 ft of water. The expln caused sufficient damage to sink the ship. Defense officials believe that only the surface has been scratched in developing uses for FAE weapons. Fuel air expls open a potential for increasing blast effects while reducing wt.

Guidance seekers can be added for a high-speed version, the washout size can be increased, the cloud detonation can be incorporated in missile systems, standoff capability & the modular weapons concept all apply to FAE (Ref 13)

Fahrn's Explosive (Fr), patented in 1898 & 1899, contained AN 86, NG 5, resin 5 and K chlorate 4%. Ref: Daniel (1902), 294

Failure Analysis. A rigorous scientific investigation, Failure analysis is an examination of failed parts, operating conditions, factors affecting performance, problem history, and other pertinent factors. Qualified experts in several disciplines can then recommend definite corrective action. One common reason for failure is material properties. Chemical analysis, mechanical testing, or structural studies will usually confirm or eliminate this failure type. Another reason for failure is operation of the part in an environment not contemplated by the designer. In analyzing a material involved in a failure, optical and electron microscopy can be used along with X-ray diffraction analysis, thermal analysis, gas chromatography, etc. If actual mechanical failure has taken place, then fractography can be used to detect overloading, environmental incompatibility, or fatigue. Refs: 1) Laboratories Highlights, Vol 2, No 1, May 1972, The Franklin Institute Research Laboratories 2) Explo&Pyrots 5(8)(1972)

Failure Density. The minimum density below which detonation will fail. See Critical Density, Vol 4, pp D190 to D193. Also under Detonation Velocity-Charge Density Relationship, Vol 4, pp D643 to D646 and pp D646 to D652

Failure in Detonation. See Fading or fadeout of Detonation in Vol 4, p D223-R

Failure in Detonation of Coal Mining Explosives. See Vol 4, p D347-R, under "Detonation, Failure of Coal Mining Explosives in a Bore Hole"

Failure Diameter. The minimum diameter below which propagation of detonation does not take place. Also known as critical diameter or limiting diameter. See Vol 4, p D660-L. Also under Detonation Velocity-Charge Diameter Relationship, Vol 4, p D641-R and Vol 3, p C560-R and C561-L. For information on critical diameters of (a) Liquid explosives, See Vol 4, p D197-L and D653-L b) Powdery explosives, See Vol 4, D653-L c) HEs, See Vol 4, pp D560-D562

Failure Length of Propagation of Detonation. See Vol 4, pp D199-L to D201-L under Critical Length of Propagation of Detonation

Fajans, Kasimir (1887— ). A Ger physicist noted for his work on radioactive substances and the discovery of radioactive element Bv (brevium), also known as uranium Xg. It has a half-life of only 1.65 mins. He is also known for Fajans-Sodd Law which states that when an α-particle is expelled from a radioactive substance the product is two places lower in the periodic table. A β-ray change, or expulsion of an electron, produces a rise of one place. Refs: 1) Hackh's (1944), pp 330-R (Fajans) and 142-R (Brevium) 2) Anon, "The International Who's Who" (1973–74)

Falcon and Falconet

Falcon was a Culverin type artillery piece of about 16th century which, accdg to Dupuy & Dupuy (Ref), weighed 800 lbs, had bore of 2.5 inches, length 6.0 ft and fired projectiles weighing 3.0 lbs. Its point blank or effective range was 400 yds and maximum range 2500 yds. Falconet was its smaller version, weighing 500 lbs, having bore of 2.0 inches, length 3.7 ft and weight of projectile 1.0 lb. Effective range was 280 yds and maximum range 1500 yds. Note: Culverins are briefly described in Vol 3 of Encycl, p C573-L. Ref: R.E. Dupuy & T.N. Dupuy, "The Encyclopedia of Military History", Harper & Row, NY & Evanston (1970), p 453 (Table)

**Falkenstein, K. von** patented in 1892 the smokeless proplct called Cibalite. See Vol 3 of Encycl, p C322-R

**Falkenstein & Petry** patented in 1884 in England a plastc expl, called Kinetite. It consisted of Nitrobenzene 16.00 to 21.00, gelatinized with small quantity (0.75–1.00) of soluble NC, mixed with finely pulverized K chloride 75.00–82.50 and precipitated Sb sulfide 1.00–3.00%. It was claimed that Sb sulfide served as a regulator of expln. *Ref:* Daniel (1902), 295 & 392

**Fallex.** (Abbr for Fall Exercises) A big training exercise without troop movements, carried out each autumn by NATO. Its object is to check on the efficiency and reliability of the communications system of the collective defense organization. *Ref:* P.G. Thillauld, "Révue Militaire Générale", Berger-Kevrault, Paris, June 1963, pp 7–19

**Fallhammerprobe or Fallhammerprüfung** (Ger for Falling Hammer Test). See IMPACT SENSITIVITY OR SHOCK SENSITIVITY TEST in Vol 1, p XVII and F1 (Figure of Insensitivity Test) described on p XII

Additional Refs are listed in Vol 4, p D304-R

**Falling Ball Test, as Conducted at Atlas Chemical Industries, Inc, Valley Forge, Pa.** employed a ball weighing 80g and reported results in inches. The following results are listed: Barium Stophnite 12, LMR (Lead Mononitrocinnamate)16 and KDNBF (Potassium Dinitrobenzofuroxan) 14. *Refs:* 1) Atlas/Aerospace, No 8, Dec 1969. Atlas Chemical Ind, Inc, Valley Forge, Pa 19481. 2) Expls&Pyrots 3(3), 1970

**Falling Ball Test** as conducted at Kankakee Ordnance Works, Joliet, Ill employed a 8.33g ball for testing impact sensitivity of LA. See under Ball Drop Test in Vol 1, p A573-L

**Falling Weight Test.** Same as Drop Weight Test. See Impact Sensitivity or Shock Sensitivity Test in Vol 1, p XVII. See also list of Refs on Impact in Vol 4, p D391-R

**Fallout.** See under Atomic Energy in Vol 1, p A502-L

**False Ogive.** See WINDSHIELD, listed under Ballistic Cap in Vol 1, p B5-R

**Fanno Line and Rayleigh-Mikheil’son Line.** See Vol 4, p D348-L under Detonation, Fanno Line

**Fans and Blowers.** *Fans* are devices for transferring vapors, air or other gases for the purpose of ventilation, supplying draft to boilers and furnaces, moving large volumes of gas thru ducts, supplying air for drying, conveying materials suspended in a gas stream, removing fumes, etc. Fans may be classified as low pressure compressors (be-
low 0.5 psi pressure head). The most common types of fans are centrifugal and axial-flow. Blowers (such as turboblowers and rotary blowers) are compressors for handling large volumes of gases at pressures from 0.5 psi to about 40 psi. (See also “Compressors” in Vol 3, p C494)


Farad. A unit of electrical capacity; the capacity of a condenser charged to a potential of one volt by one coulomb of electricity. It is 10^{-9} CGS (centimeter-gram-second) unit
Ref: Hackh’s (1944), 331-R & 332-L; 50-L (ampere), 229-R (coulomb), 590-R (ohm) and 899-R (volt)

Faraday (F). The quantity of electricity which liberates one gram equivalent of a metal in electrolysis. 1F = 96,489 coulombs = 6.02 \times 10^{23} electrons per mole
Ref: Hackh’s (1944), 332-L

Faraday, Michael (1791–1867). A Brit chemist and physicist noted for liquefaction of gases, the effect of electric current on the magnetic needle, electrolysis, and as discoverer of benzene. He also introduced the law stating that the wt of an ion deposited electrolytically is proportional to the strength of the current passing thru the soln.

The washing bottle, currently used in labs was his invention and so was ammonia tube, a V-shaped tube of strong glass which, inverted, is used for distillation, purification and crystallization of liquids under pressure
Ref: Hackh’s (1944), 332-L

Farmer’s Dynamite. An inexpensive Brit 40% strength exp[ (See Strength of Explosives in Vol 1 of Encycl, p XXIV) employed for breaking up subsoil, making holes for trees, poles or other agricultural purposes. It contains NG ≈ 39.5 (gelatinized with NC ≈ 0.75) absorbed by dry wood meal ≈ 16.5, NaNO3 and MgCO3 1%. It differs from ordinary American 40% straight dynamite in being less subject to exudation because the NG is gelatinized and a larger percentage of wood meal is used
Ref: Marshall 1 (1917), 370

Farmer’s Test for Stability. See Vacuum Stability Test in Vol 1 of Encycl, p XXVI

Fasan (Pheasant) Powder. One of the varieties of older German shotgun propellants. It consisted of greyish-yellow grains and the charge was 2.65g. Specially designed for shooting pheasants
Ref: Marshall 1 (1917), 330–31 (Included in microgram)

FASP. In Rocket Technology it stands for “Final Average Sustained Pressure”, and refers to the average pressure near the end of a test run before the pressure has begun to fall off markedly
Ref: F. Bellinger et al, IEC 38, 166 (1946)

Fast Burning Gasless Mixture, which contains: CuO 80 & Al (grained) 20%, is suitable as an incendiary. It develops high pressure on fast burning by sublimation of copper
Ref: W.A. Show, “Development of an Incendiary Pellet”, TCR–59, Technical Command, Army Chemical Center, Maryland (5 May, 1950)

Fast Neutron Activation Facility at Picatinny Arsenal. A new fast neutron activation facility installed at PicArsn consists of: 1) A Kaman Nuclear Model A711 sealed-tube accelerator for the generation of 14 MEV neutrons by the deuterium-tritium reaction 2) A dual-axis rotating head for the uniform irradiation of samples 3) A sample transfer for the automatic transfer of explosive samples to the accelerator target and back to count station at speeds of 50 ft/sec 4) Two
matched 3-inch x 3-inch sodium iodide scintillation crystals in a large lead shield and
5) Various associated nuclear counting equipment. It is used primarily for rapid, non-destruc-
tive quantitative determination of macro quantities of elements (nitrogen, oxygen, lead) in explosives. Trace concentrations of elements can be determined, and the neutron generator can be used as a neutron source for radiation studies
Refs: 1) O.E. Sheffield, ExplsLabNews 3 (Nov 1968), PicArsn, Dover, NJ, 07801
2) Expls&Pyrots 2(1) (1969)

**Fast Photography.** See CAMERAS, HIGH-SPEED PHOTOGRAPHIC in Vol 2, pp C13-L to C19-R

**Fast Reactions in Solids.** They can be considered from an expl standpoint to be complete in less than one msec. Low intensity activation (heat, shock, light, ionizing radiation, "spontaneous") can give rise to a series of stages of reaction, each of which can be terminal or skipped, which lend themselves to study with the proper instrumentation and technique: initiation of decompn in a definite region, change from decompn region to burning region, acceleration of burning and sharp transition to low-vel deton, propagation of low-vel deton, change to high-vel deton, propagation of high-vel deton. Useful tools in the slower stages are electron microscopy and electron diffraction, while high speed photography and electronic methods can be used in the later stages

**Fats, Fatty Oils, Tallow, Butters, Waxes and Fatty Acids** are general terms for greasy, solid or liquid substances occurring in animals and vegetables
In composition, they are glycerin esters of one or several fatty acids, such as lauric, oleic, palmitic, stearic, etc. Fats are neutral substances, insoluble in water but soluble in ether. Fatty oils are fats that are liquid at ordinary temperatures, while tallow and butters are solid or semisolid at ordinary temperatures. There is no rigid distinction among these terms; for example, "coconut oil" is often called "coconut butter". Fatty oils are sometimes called "fixed oils" to distinguish them from volatile, ethereal or essential oils. There are also mineral, or petroleum, oils which differ from fatty oils in composition but possess some common properties. For instance, both fatty oils (such as castor oil) and mineral oils possess lubricating properties
Waxes are solid or semisolid plastic substances consisting of mixtures of esters, fatty acids, high molecular-weight alcohols and even hydrocarbons. Waxes differ from fats in that they are the esters of monohydrac, high molecular weight alcohols, whereas fats are the esters of trihydrate, low molecular weight alcohols, such as glyc erin. Examples of waxes: beeswax, camauba, spermaceti. There are also substances obtained from mineral sources which resemble waxes in appearance and in some properties, such as paraffin, cetesin, montan wax, etc

Fatty acids are aliphatic monocarboxylic acids, many of which occur as esters of glyc erin (glycerides) in natural fats and oils. For example, acetic, butyric, propionic, lauric, myristic, palmitic, margaric, stearic, oleic, linolenic, ricinoleic, etc
Some fats, oils and waxes have been used as ingredients in explosive compositions, such as plastic explosives. They can also be nitrated to give nitro- or nitrate compounds
1) E. Montagne, BullFr [5], 1, 291–2(1934)
FAUSTPATRONE

Charger. A shaped charge antitank rocket fired from a tubular discharger, used during WWII against tank. The smaller model, Faustpatrone 1, was later called Panzerfaust 30, Klein, while the larger model, Faustpatrone 2, was called Panzerfaust 60 and it weighed only 13.4 lbs. Warheads of each model contd HE shaped charges, called in Ger Hohlладungen (Hollow Charges). These weapons could be fired by one man, similarly to Bazooka, developed in 1942 in USA (See Vol 2 of Encycl, p B26). More detailed description of Faustpatrone is given in Ref (See Fig 1).

Ref: Fedoroff et al, PATR 2510 (1958), p Ger 46 (Includes 7 refs).

Faversham Mixture, called by Daniel Fulmicoton Nitraté de Faversham, consisted of NC 51.6 & Ba nitrate 48.4%. This compo was practically the same as Tonite No 1, patented in 1874 in England by Trench, Faure & Mackie, which contd NC 51 & Ba nitrate 49%. There was also Tonite No 2, which contd as the 3rd ingredient carbon and Tonite No 3 (patented by Trench in 1889), which contd NC 14.55 to 19.00, m-DNB 13.20 to 13.00 & Ba nitrate 72.25 to 68.00%. Some of these mixts were manufd in England, Belgium and USA. The compo of Belgian mixt was: NC 50, Ba nitrate 40 & saltpeter 10%.
These mixts were suitable for underwater expls and some of them were used for loading torpedoes.
Ref: Daniel (1902), 769–70 (Tonite or Fulmicoton Nitraté de Faversham).

Faversham Powders. Several of the Brit Favier type permissible expls, md by the Cotton Powder Co Ltd in Kent, England, initially under the formula: AN 85, DNB 11, NH₄Cl 1.5, NaCl 2.5%. This was later

Faober, Mockie & Trench patented in 1873 in England an expl based on NC to which were added rosin, lacquer, ozokerite, colloidion, glycerin, and charcoal or soot. The same inventors patented in 1876 expls in which NC was substituted by nitrated sainfoin, esparto grass, agave, hemp, flax, straw, hay, Amer aloe and yucca.

Faustpatrone (Ger for Fist Cartridge), also known as "German Recoilless Grenade Dis-
altered to No 1: AN 84-86, TNT 10-12, 
NH₄Cl 1-2, NaCl 1-3, water 0-2.5%; and
No 2: AN 87-93, DNT 9-11, water 0-1%.
Another formula also called No 2 was AN 
47.5, KNO₃ 24, TNT 10, NH₄Cl 18.5%; this 
one has a limit charge of 24 oz and power 
(swing of Bal Pend) is 2.61 inches, compared 
with 2.7-3.1 inches for 8 oz of a 40% Ameri-
can Straight Dynamite

Accdg to Ramsey & Weston (Ref 4), Faver-
sham Powder was practically flameless, a 
property which was achieved by impregnating 
the components with the so-called Trench’s 
Fire Extinguishing Compound which consisted 
of sawdust treated with solns of Amm sulfate 
or sulfanide. This gave br Faversham Powder:
AN 85, DNB 10 & Trench’s Compound 5%
Refs: 1) Daniel (1902), 295 2) Thorpe 2 
(1912), 416 3) Marshall 1 (1917), 390 
4) Ramsey & Weston (1917), 181 5) Colver 
(1918), 142, 169 & 249

FAVIER EXPLOSIVES (Belg, Fr & Brit).
Accdg to Daniel (Ref 1), the original type 
consisted of a cartridge consisting of AN 
91.5 & MNN (Mononitronaphthalene) 8.5%, 
loose in the center and compressed on the 
outside. It is not stated when such cartridge 
was introduced

Accdg to Gody (Ref 1a, pp 589 & 591), 
Favier expls are mixts of Amm or Na nitrate 
with MNN or DNN (Dinitronaphthalene), 
invented in 1888 in Belgium

Accdg to Marshall(Ref 2), Favier introduced 
is expls in 1884 into industry, especially 
in coal mining, because they possessed a 
low temp of expln and contained sufficient 
oxygen for complete combustion of C to CO₂, 
thus developing no poisonous CO₂.

Accdg to Molina (Ref 3), the following 
Favier expls was introduced in 1885 in Belgium:
AN 91.5 & MNN 8.5%, which is identical with 
compa listed in Gody (Ref 1, p 296)

Accdg to Gody (Ref 1a, p 593), the Société 
Belge des Explosifs Favier, at Vilvorde 
(Trois Fontaines) manufd before WWI three 
types of Favier expls:
No 1 (Antigrisou Favier) with temp of expln 
2000°C contained AN 87.6 & DNN 12.4%
No 2 (Antigrisou Favier) with temp of expln 
1878°C contained of No 1 to which 8.0 
parts NaCl was added
No 3(Antigrisou Favier) with temp of expln 
1400°C contained AN 77.6, TNN 2.4 & Amm 
chloride 20.0%

Other Belg Favier expls are listed by 
Gody on p 712. They are Favier II: AN 
80.9, DNN 11.7 & Amm chloride 7.4% and 
Favier IV: AN 95.5 & DNN 4.5%

Favier expls were introduced in France 
and the following “Explosifs de genre 
Favier” were manufd before WWI by the 
Société Française des Poudres de Sûreté:
a) Poudre Favier n°1A: AN 88 & DNN 12%; 
b) n°1B:AN 67, Na nitrate 18 & MNN 15%; 
c) n°2: AN 44, Na nitrate 37.5 & MNN 18.5%; 
d) n°3: Na nitrate 75 & MNN 25%; e) Grisou-
mine roche: AN 91.5 & DNN 8.5% and f) 
Grisoumine couche: AN 95.5 & TNN 4.5% 
(Ref 1a, p 594). (Couche: max temp 1500°, 
permisssible in coal seams; roche: max temp

<table>
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<tr>
<th>Component</th>
<th>Designations</th>
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<tr>
<td>AN</td>
<td>78.7 88.5 87.5 95 91.5 87.4 15 90 86.5</td>
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<tr>
<td>K nitrate</td>
<td>- 5 - - - - - - 5 5</td>
</tr>
<tr>
<td>Na nitrate</td>
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<tr>
<td>DNN</td>
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<tr>
<td>TNN</td>
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</tr>
<tr>
<td>TNT</td>
<td>21.3 6.5 12.5 - - - - -</td>
</tr>
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</table>

Note: Poudres 0a and 0b were known as Grisoumite N9a and 
Grisoumite N0b (Ref 8)
Table F2

<table>
<thead>
<tr>
<th>Designation</th>
<th>Components</th>
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<tr>
<td></td>
<td>AN</td>
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<tr>
<td>Grisou-naphalite</td>
<td>95</td>
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<tr>
<td>couche</td>
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<td>Grisou-naphthalite</td>
<td>90</td>
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<td>sulpétrie</td>
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<td>86.5</td>
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<tr>
<td>Poudre Favier pour</td>
<td>87.5</td>
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<td>mines nongrisouteuses</td>
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<tr>
<td>Favier belge anti-</td>
<td>81</td>
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<tr>
<td>grisoulete</td>
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<tr>
<td>Baelénite</td>
<td>93 and TNT 7%</td>
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</tbody>
</table>

1900°, permissible in accompanying rock

Vennin, Burlot & Lécorché (Ref 5, p 527) list nine French "Poudres Favier", also known as "Grisounites", "Poudres de sûreté" & "Naphthalites". Same expls manufd by les Usines de l'État (Poudrière d'Esquerdes, Vonges, Saint Chamas & Sevan-Livy) were known as "Explosifs type N". Table F1 lists these expls

Pepin Lehalleur (Ref 6, p 352) gives compositions of the following Explosifs Favier manufd by les Usines de l'État as of 1935 (See Table F2)

Accdg to Marshall 3 (Ref 4, pp 118-19) a number of Favier type explosives have passed the Buxton Test for British "permitted" explosives. They all contained a considerable proportion of NaCl. He lists among such expls: Ammonites No 1 & No 2, Bellite No 2, Celmonite, Gathur Powder, Haswellite, Hawkites, Norsabite, Roburite and Talbitite

In other British Favier type expls NaCl was replaced by Amm chloride and a considerable proportion of potassium nitrate was introduced so that KCl could form on expln. They included Denaby Powder, Kentite and Tolamex

Davis (Ref 7, pp 350-52) describes the same Favier type expls as did Pepin-Lehalleur but he includes also Grisou-tétylrite couche and a number of Grisou-dynamites or Grisou- tines. All of these expls are described here under "Grisou Explosifs"


Favorit. One of the names for Koronit, which was a Ger expl used during WWI, as supplement to nitro compds which were in short supply. Compo given in Marshall (Ref 2) came from Ref 1. It was K and/or Na chlorate 70-80, Nitro-derivs of toluene and/or diphenylamine 1-5, solid hydrocarbons and/or oils or fats 3-5 and NG 2-6%


FAX (Fuel-Air Explosives). See FAE and FAX

F-Bomb. Brit for Fragmentation Bomb

F.E.-1, F.E.-2 and F.E.-3. See Explosivos F.E.-1, F.E.-2 and F.E.-3 in this Vol and in Vivas, Feignespan & Ladreda 2 (1946), p 384
Federal Fireworks Regulations. New regulations list all proposed fireworks devices permitted by HEW (the Dept of Health, Education and Welfare). Modifications include banning of bottle rockets and firecrackers, requiring safety fusing on all articles which employ fusing, providing for minimum wall thickness on tubular articles and standardizing labeling requirements to alert parents to the potential danger.


Fedoroff, Basil T. (1891— ). Russian born scientist & engineer (Merv, Russian Turkestan) who became an American citizen in 1927. He was educated before WWI at the Imperial Tomsk Institute of Technology (Chem Engr) & University of Paris, Sorbonne (Ingénieur Docteur, 1940). From 1941 he worked in the USA in the field of expls & propbnrs in private industries and at Picatinny Arsenal where he was the author of a number of technical reports (PATR's) & lectures. His most important publications include: "A Manual for Explosives Laboratories", Lefax, Philadelphia, Pa, 4 Vols (1942–46) in collaboration with G.D. Clift; "Dictionary of Russian Ammunition and Weapons", PATR 2145 (1955); "Dictionary of Explosives, Ammunition and Weapons (German Section), PATR 2510 (1958); and as senior author of the "Encyclopedia of Explosives and Related Items", PATR 2700, Vols 1–6 (1960–73). Dr Fedoroff is a unique repository of historical facts and is an internationally known expert in explosives, propellants & pyrotechnics.

Ref: Oliver E. Sheffield & Gunther Cohn (1973).

Feeder and Feeding Mechanisms are devices intended for continuous and automatic carrying of materials to feed various units of a plant. Liquids and gaseous materials are usually fed by pumps, fans and pressure vessels. Solids, however, vary so greatly in character that they need special equipment. There are many types of feeders for solid materials. Most of them are described briefly by R.W. Hyde in Perry's "Chemical Engineers' Handbook", McGraw-Hill, NY, 3rd ed (1950), pp 1370–76 and in 4th ed (1963), 7–32ff.

Fehlisen (Poudre de) or Haloxyline. An older powder: saltpeter 77.59, sawdust 15.52, charcoal 5.17 & K ferrocyanide 1.72%.

Ref: Gody (1907), 173 (Compn is given in parts: saltpeter 45, sawdust 9, charcoal 3 & K ferrocyanide 1).

Fehling, Herman von (1812–1886). A German chemist known as an investigator of orgn compds, and of analytical methods. He proposed a reagent, known as Fehling's Solution, still serving for lab detection and determination of reducing sugars (Ref 1). The Association of Official Agricultural Chemists (USA) and most other organizations use at the present time the Soxhlet modification of Fehling's Reagent, which is conducted in the following manner: Prepare No 1 soln by dissolving 34.639g CuSO₄·5H₂O in distilled water and dilute to 500ml; prepare No 2 soln by dissolving 173g of Rochelle salt (KNa₃C₅H₄O₆·4H₂O) with 59g Na hydroxide in w and dilute to 500ml. Allow the solns to stand for 2 days and then filter thru prep'd asbestos (Ref 3). Standardize the reagent against a soln of dextrose of known strength. As a practical application of F's soln may be cited den of glucose and sugar in glycerin used in manuf of NG.

Procedure: Mix equal volumes of No 1 & No 2 solns in ams sufficient to fill half of a test tube and fill the remaining half with an equal volume of glycerin. Stopper the tube so that no air remains under stopper and let it stand for 12 hrs. A reddish ppt indicates the presence of reducing agents which will interfere in testng for glucose or sugar, unless the ppt is removed by filtration.
If the previous test is negative, transfer the contents of the tube (without filtering) into a larger tube, add more F's soin and heat the liquid for a few minutes. The resulting red ppt of CuO (if present) is filtered, washed with w, ignited and weighed as CuO. Compare the wt with that of "standard" obt by treating a dextrose soin of known concn.

For determination of sugar (saccharose) in glycerin, dilute a known vol with two vols of w and, after acidifying it with few drops of HCl, heat just to boiling and nearly neutralize with Na₂CO₃. Add an excess of F's soin, heat for few mins and treat the resulting red ppt as described above.


Felixdoll Factory Ammonals (Austrian). See Vol 1, p A289 (Table)

Felixite. Brit sporting bulk powders. Some of the older types are listed in Ref 1 and some of the newer ones in Ref 2. Examples: 1) Felixite 1906 (fibrous, 42 grain bulk): NC (insol) 40.5, NC (sol) 20.5, metallic nitrates 30, nitrohydrocarbon 5.0, vaseline 2.7, moisture 1.3% 2) Felixite NE 1912 (fibrous, 36 gr bulk): NC (insol) 50.0, NC (sol) 25.8, metallic nitrates 12.0, nitrohydrocarbon 7.0, vaseline 3.5, moisture 1.7 3) Neonite 1907 (gelatinized, 30 gr bulk): NC (insol) 73.0, NC (sol) 9.0, metallic nitrates 10.5, vaseline 5.9, moisture 1.6. Refs: 1) Marshall (1917), 236 2) Ibid 3 (1932), 96

Feigl, Fritz (1891— ). Austrian analytical chemist; educ Poly Inst of Vienna (BChE, 1914; DSc, 1920); assoc since 1940 with Ministry of Agric, Brazil; developed spot test methods for qualitative analysis requiring min amts of sample and reagent and very simple apparatus.


Fehleisen & André patented ca 1866 Black Powders contg K ferrocyanide in lieu of sulfur. Another variety contg K ferrocyanide which was patented by Fehleisen & Bleckmann.

Refr: Daniel, Dict (1902), 298 & 367

Fenchone (1,3,3-Trimethyl-2-norcamphaneone), C₁₉H₂₄O; mw 152.23; colorless oil with camphor-like odor, sp gr 0.9465 at 19°, fp 5-6°, bp 193-195°; insol in w, v sol in alc or eth. This ketone is found as dextro-fenchone in oil of fennel, and as levo-fenchone in oil of turja. It is a solvent for NC forming a molecular compd in solns and has been used as moderator and gelatinizing agent in single-base or double-base propnls.


Fennion Powder — patented in England in 1879 consisted of 90p of Black Powder with 10p of a product obtained on nitration of naphthalene (1p) with 4 parts of nitric acid (d 1.4). The nitrated product consisted of mononitronaphthalene with a small amount of the dinitro-compd.

Refr: Daniel (1902), 298

Fenion Fire (Feu liquide in Fr.). Incendiary compn consisting of a soln of yellow phosphorus in CS₂. After evapn of the solv, phosphorus catches fire and ignites the surrounding flammable materials. Darapski proposed charging incendiary projectiles with the soln consisting of yellow phosphorus (3p) and CS₂ (1.3p). Inside this soln was placed a leather bag contg petr oil with other combustible materials.

Refr: Daniel (1902), 153
**Fenices** (Brit & Fr). A series of Dynamites patented in 1899: a) NG 25, K nitrate 34, Na nitrate 1 & sawdust 40% b) NG 25, Na nitrate 35 & rye flour 40% c) NG 30, Na nitrate 52 & sawdust 38% d) NG 30, Na nitrate 30 & rye flour 40% Re/s: Giusa, Trattato VI(1)(1959), 386

**Fenton's Powders.** Explosive mixtures of K chlorate, K ferrocyanide and sugar patented in England in 1873 (Ref 1), Pérez Ara (Ref 3) gives for Polvora de Fenton: KClO₃ 66, K₄Fe(CN)₆ 17 & sugar 17%, while Giusa (Ref 4) gives for Polvere Fenton (1873): KClO₃ 50, K₄Fe(CN)₆ 25 & sugar 25%. The compo given by Giusa is identical with that given in Davis (Ref 2) and in Vol 1 of Encycl, p A507-L for Augendre Powder (White Powder), proposed in 1849 in France, and used later in other countries Re/s: 1) Daniel (1902), 298 1a) Gody (1907), p 264 (Poudre de Fenton) 2) Davis (1943), 358 3) Pérez Ara (1945), 212 4) Giusa, Trattato, VI(1)(1959), 392-R

"Ferdinand". Ger tank (Panzer) of WWII, known as JagdPz VI(?), Tiger Porsche or SdKz 184. It was Tiger 1 (II) of Henschel converted by Porsche into self-propelled motor carriage. It was equipped with one MG and one long-barreled 88mm Gun (8.8cm KwK 36). It was superseded by "Elefant" (See in this Vol) Re/s: 1) G.B. Jarrett, "Achtung Panzer", "The Story of German Tanks in WWII", Great Oaks, RD 1, Aberdeen, Md (1948) 2) Fedoroff et al, PATR 2510 (1958), p Ger 123-R, under PANZER

**Fergusonite.** A natural inorg substance discovered among the feldspars of Norway, but it is found also in Sweden, USA and Africa. It is an oxide of yttrium, erbium, niobium & tantalum - (Y, Er, Nb, Ta)O₄ contg small amounts of helium, cerium, uranium, etc. It is a gray, brown or black solid, sp gr 5.6–5.8 and hardness 5.5–6.5 (Ref 2). Accdg to Daniel (Ref 1), when fergusonite is heated, it suddenly flashes, developing a very high temp and pressure due to the evoln of a large vol of He. Its heat of expln is ca 800cal/g Re/s: 1) Daniel (1902), 298 2) CondChem-Dict (1961), 486-R

**Fermentation.** Fermentation is defined (Ref 3) as the production of chemicals by a series of enzyme catalyzed reactions with bacteria, yeasts, or molds under aerobic or anaerobic conditions. At present, fermentation is used to produce complex molecules not easily synthesized such as penicillin and other antibiotics, vitamin B₁₂, and enzymes. Formerly, glycerine (See Fermentol), acetone, butanol, and citric & lactic acids were some of the chemicals produced by fermentation process. Synthesis is now a more economical route to these materials (See also Refs 1 & 2) Re/s: 1) P.A. Wells & G.E. Ward, IEC 31, 172–77 (1939) 2) H.E. Silcox & S.B. Lee, IEC 40, 1602–08 (1948) (First of a series of articles on fermentation) 3) Kirk & Othmer, 2nd edit 8 (1965), 871–80 (R.G. Anderson, Fermentation)

**Fermentol** (also Protol Glycerine or Protaglycerine). A glycerine produced in Germany from sugar by a fermentation process. Trimethylene glycol in the product evolves more heat than glycerine on nitration, is more soluble in the mixed acid, and thus contributes to fuse-offs Re/s: 1) Naum, NG (1928), pp 31, 229 2) Marshall 3 (1932), p 42

**Ferric Azide.** See under Azides in Vol 1, p A543

**Ferric Azide, Basic.** See Vol 1, p A543-R

**Ferric Ferrocyanide or Prussian Blue, Fe₄[Fe(CN)₆]₃.** mw 859.29, dk blue crystals, mp – dec; insol in cold w, alc or eth; sol in
HCl & concd sulfuric acid. Prep'd as described in Ref 2 under Iron blues. Used as an ingredient of some expl comps

Ferric Nitrate (Iron Nitrate), Fe(NO₃)₃·9H₂O; mw 404.02, It viol monoc delq crystals, mp 47°, dec at 100°; v sol in w & alc. Can be prep'd by the action of concd nitric acid on scrap iron or on iron oxide, followed by crystm. It is a strong oxidizing agent and is considered to be dangerous as a fire hazard. Used in analytical chemistry

Ferric Oxide or Red Iron Trioxide (Hematite), Fe₂O₃; mw 159.70, md or blk trigonal crystals, sp gr 5.12, mp 1560°(dec); insol in w, sol in HCl & other acids; found in nature as hematite and is a by-product in some industries. Can be prep'd by dehydrating ferric hydroxide or calcining ferrous oxalate or sulfate. Used in magnetic tapes in electronics and as an ingredient of some expl comps

Ferric Picrate. See under Picrates

Ferric Triazine. Same as Ferric Azide, Vol 1, p A543

Ferricyanides. See the cation (potassium, sodium, etc) for particular ferricyanides

Ferri-ferrous Oxide or Magnetite, also known as Iron Oxide, Black or Ferroso-ferric Oxide, Fe₃O₄; mw 231.55, black cubic crystals or amorphous powder, sp gr 5.0, mp 1538°(dec); insol in w, alc or eth; sol in acids; occurs in nature as mineral magnetite. Can be prep'd in pure state by dehydrating pptd hydrated ferric oxide, followed by reduction with hydrogen. Used as an ingredient of some expl comps and in ferrite (qv) for electronic industry

Ferrifracteur. A safety expl contg AN 90 & DNB 10%
Ref: Daniel (1902), 299

Ferrite. Iron which, in pig iron or steel, has not combined with carbon to form cementite (Fe₃C). It exists in α, β, γ and δ forms, which vary in magnetism and ability to dissolve cementite. Name also applied to compd NaFeO₂ (called Na ferrite), to ferromagnetic oxides having a definite crystal structure (spinels) and the formula M⁺⁺Fe₂⁺⁺O₄ of which the divalent metal may be Fe, Ni, Zn, or Mn. The magnetic props vary accdg to the divalent atom present, and ferrites are now tailored for their desired effect, as Ni-Al ferrite

Ni⁺⁺₀.₈₆Ca⁺⁺₀.₁Co⁺⁺₀.₀₂Al⁺⁺₀.₃Fe⁺⁺₁.₇O₄

Used in missile guidance systems; in electronics as rectifiers, on memory or record tapes; for permanent magnets; also in radar, radio, television and computers
Ref: 1) Cond-ChemDict (1961), 491-L  2) Kirk & Othmer, not found

Ferro-Alloys, Chrome Metal, and Spiegeleisen are covered by Federal Specification QQ-F-145, April 30, 1964, with Amendment 1, January 18, 1967. The following alloys are covered by this spec: Ferrochromium, Chrome Metal, Ferromanganese, Ferromolybdenum, Ferrosilicon, Ferrotitanium, Ferrovanadium and Spiegeleisen
Their compositions and tests are given in the spec. They are intended to be used as alloying additives in the melting and preparation of ferrous and nonferrous alloys
Ref: Cond-ChemDict (1961), 491-L
Ferroboron. A ferro-alloy averaging 16.2% boron used as hardening agent in special steels. It also is an efficient deoxidizer. Boron steel is used in controlling the operating rate of the uranium-graphite piles used to produce plutonium.

Refs: 1) CondChemDict (1961), 491-R
2) Kirk & Othmer, 3 (1964), 605-08 (under Boron and Boron Alloys by F.E. Bacon)

Ferroconcrete. One of the names for concrete reinforced by steel in various forms, usually rods.

Refs: 1) CondChemDict (1961), 295 (Concrete); 491 (Ferroconcrete) 2) PATR 2700, Vol 2 (1962), pp C125-R & C126-L (Cement and Concrete in Ordnance) 3) Kirk & Othmer, not found

Ferroocene or Diclopentadienyl-iron, (C₅H₅)₂Fe. A coordination compd of ferrous iron and diclopentadiene in which the org portions have typically aromatic chem props. It is an om cryst compd with camphor-like odor, mp 173-74°, resists pyrolysis at 400°and is resistant to UV light. Insol in w; sl sol in benz, eth & petr eth. Can be prep from ferrous chloride and cyclopentadiene sodium. Used as additive to jet fuels and furnace oils to improve efficiency of combustion and to eliminate smoke; antiknock additive for gasoline; high temp lubricant; curing agent for rubber & silicone resins; intermediate for high temp polymers and UV absorber. It was suggested for coating missiles and satellites.

Refs: 1) Beil 5, 495 (Diclopentadiene) 2) CondChemDict (1961), 491-L & R (Ferroocene) 3) Kirk & Othmer 6 (1965), 696 (under Cyclopentadiene)

Ferrocyanides. See cation (potassium, sodium, etc) for particular cyanides. Acqdg to Marshall 1 (1917), K ferrocyanide has been used as a constituent of blasting expls.

Ferrosilicon are compds prep by fusing iron and silica in an electric furnace at high temps. Some of the high silicon varieties, particularly 50/50 compd, are expl and are dangerous to transport and to handle. FeSi is of unknown toxicity. Moisture, steam, or water decompose it and impurities liberate phosphine and arsine with water. Expl and fire hazards are considered moderate and arise from the reaction with water. For shipping purposes FeSi with Si 30-70% is considered a flammable solid and must carry yellow labels. If the Si is less than 30 or more than 70%, the material is not considered hazardous.

J. Sato (Ref 10) reported FeSi decreased the rate of deton of RDX and TNT. Médard (Ref 4) reported that CUP of several expls increased slightly with 10% FeSi: CUP of PA increased from 100 to 102%, TNT 94.0 to 94.5, PETN 146.5 to 148 and RDX 134.5 to 141%. Sartorius (Ref 5) reported slight increases in Trauzl Tests of the same four expls with 10% FeSi. Refs 6, 7, 8, 9, 10 and 11 give formulations from recent patents where FeSi was added. In general, 10% FeSi gave slight improvements in props of the compds in which it was included.

Ferrous Acetylide. See Iron Acetylide in Vol 1, p A76-R under ACETYLIDES AND CARBIDES

Ferrous Ammonium Sulfate or Mohr's Salt. \( \text{FeSO}_4 \cdot (\text{NH}_4)_2 \text{SO}_4 \cdot 6\text{H}_2\text{O} \); mw 392.16, blue-gm monocrys, sp gr 1.864, mp – dec; sol in w, insol in alc. Can be prep by mixing ag solns of equivalent wts of Amm and ferrous sulfates, followed by evap and subsequent crysyt. Used for \(-\text{NO}_3\) dem in inorg & org nitrates, as described under "Ferrous Sulfate and Ferrous Ammonium Sulfate in Determination of Nitrates"


Ferrous Azide. See Vol 1, p A543-R

Ferrous Carbide. See Iron Carbide in Vol 1, p A76-R under ACETYLIDES AND CARBIDES

Ferrous Oxide (Iron Monoxide), FeO; mw 71.85, blk pdr, sp gr 5.7, mp 1420°; insol in w, sol in acids. Can be prep by heating ferrous oxalate under the hood, while avoiding inhalation of toxic CO evolved. Some ferric oxide is present as impurity. Used as ingredient of some expls


Ferrous Picroate. See under Picrates

Ferrous Sulfate (Iron Sulfate or Green Vitriol), FeSO\(_4\).7H\(_2\)O; mw 278.03, blue-gm monocrys, sp gr 1.899 at 18.0°, mp 64°, -7H\(_2\)O at 300°; sol in w, insol in alc. Can be prep by the action of dil sulfuric acid on iron or by other methods. Used in lab for detn of inorg or org nitrates (See next item)


Ferrous Sulfate and Ferrous Ammonium Sulfate in Determination of Nitrates.

Historical: The first mention of a method was made by Grossart in 1847 (Ref 1), who titrated the nitrates in boiling sulfuric acid with a FeSO\(_4\) soln using ferricyanide as an outside indicator. Mohr (Ref 2) described in 1861 a method in which the sample was dissolved in dilute sulfuric acid and titrated at 70-80° with ferrous sulfate soln until the appearance of a brownish coloration. This method was condemned in 1862 by Fresenius and by Eder in 1877. The method was forgotten until Devender proposed in 1899 to carry the re- action over mercury with exclusion of air. The process was awkward to handle and was not adopted. A new impetus was given to the method by Bowman and Scott (Ref 3), who proposed a method which is still successfully used (with minor modifications) in many laboratory tests. The method is expanded now to determination of NO\(_3\) in organic esters, such as NG, NC, etc.

Because the end point (formation of a permanent brownish coloration) is not very sharp, the back titration method (Ref 4) was used successfully by Dr Fedoroff at the Keystone Ochm Works, Meadville, Pa and improved at PicArsn (Ref 9a). More recently, an electrometric method for detection of the end point was proposed (Refs 5, 6, 7, 8 and 11; Refs 6 & 7 are discussions of instrumental design and not primarily about FeSO\(_4\) to detn nitrate). The method developed at PicArsn for dem of N in NC is described in detail in Ref 18.

In the back titration method an excess of FeSO\(_4\) is added to the soln of the nitrate and back titrated with K\(_2\)Cr\(_2\)O\(_7\) (Ref 4). In addn to the use of K\(_2\)Cr\(_2\)O\(_7\), Kolthoff et al
adopted the use of Amm molybdate to catalyze the rather slow reduction of NO₃⁻ by Fe²⁺

In 1956, Fréjacques and LeClercq (Ref 12) suggested the use of ferrous ammonium sulfate (qv) because the Fe²⁺ in it was not as subject to oxidation by air.

A colorimetric method based on the violet color produced by ferrous sulfate in sulfuric acid in the presence of NO₃⁻ was announced by English in 1947 (Ref 9) and applied to the determination of NA and nitrosoylsulfuric acid (NSA) in spent mixed acid. Since then a number of papers (Refs 13, 14, 15-16 and 17) have extended the method to NO₃⁻, organic nitrates and RDX-HMX mixtures.

Analytical Methods: The visual determination of the endpoint (appearance of a permanent brown color) in the dead-stop titrimetric method is reported accurate to 0.03ml (Ref 3) and was used recently by Fréjacques and LeClercq (Ref 12) for analysis of Pentolites, Tetryl, NGu, NG prepns, and Nitroethane-EGDN expls.

The endpoint has been criticized as difficult to see, and if problems arise, electrometric methods are available for detection (Refs 6, 7, and 8). The back titration method (Ref 4) was used by Leith (Ref 10) for fertilizers and Potier (Ref 11) for nitrate in water and sulfuric and nitric acids.

Any of the methods mentioned are applicable to NA or to inorg NO₃⁻. Application to org nitrates depends on hydrolysis of the org compd by the sulfuric acid in which the ferrous sulfate magent is prep'd or the sample dissolved to liberate the NO₃⁻ for reaction.

The residues of the organic portion of the molecule remaining could be oxidized by the potassium dichromate used in the back titration method and so introduce errors. The dead stop method or the colorimetric method (below) might be preferred in such cases.

The references cited for the colorimetric method differ primarily in sample treatment needed to get the sample ready for analysis. The actual determination consists of adding a soln of ferrous sulfate in sulfuric acid and measuring the absorption at 510–515 nanometers. A period of 30–50 mins is needed for development of the color.

English (Ref 9) reported the development of the method for the determination of NA and nitrosoylsulfuric acid (NSA) in spent MA. Both NA and NSA give the color reaction so the total is determined, the NSA destroyed with sulfamic acid, and the NA alone detd. NSA is then the difference. The adaptation of the method to NC was described in Ref 13. The sample was dissolved in water or acetone for the determination. Interferences reported are: NO₂⁻ and S₂O₇⁻; while CrO₄²⁻, Cr₂O₇⁻, SO₄²⁻, PO₄³⁻, ClO₃⁻, SO₃²⁻, OAc⁻, and Hal⁻ did not interfere. PETN, HNMe₃, NG, and Inositol (NO₃)₆ in pharmaceutical tablets were detd (Ref 15) by extracting the org nitrate with HCl (or acet for PETN) from the excipient (lactose or mannitol), evaporating to dryness, and taking up the residue in glacial acetic acid. Na₂SO₃ was used as an accelerator in the color development stage. NMe₃, NB, MN₃ and Nitrorea gave no color.

In two papers (Refs 15 & 16), Lacetti, Semel and Roth reported use and development of the method for organic nitrates of Ordnance interest and extended the method to nitramines used in proplnt and HE comps. The reaction was not specific for -O-NO₂ since -N=O-NO₂ was found to give the same color. NG, PETN, TEGDN, Tetryl, NG all gave the same straight line when absorbance was plotted against concentration, permitting one calibration curve to be used for all. RDX and HMX also gave straight lines but of different slopes from each other and from the other materials. Since the RDX and HMX curves differ, a weighed sample of a mixture will have an absorbance between the values for the same weight of either of the pure compounds, thus permitting detn of one of them in the presence of the other. Norwitz (Ref 17) detd inorg nitrate in proplnts by extracting the NC with acet, filtering to remove the undissolved nitrate and dissolving the residue in water. Common constituents of proplnts did not interfere, but oxidizing agents caused high results and NO₃⁻ interfered.

Refs: 1) Grossart, CR 1, 21 (1847) 2) Mohr, Dingler's Polytechnisches, 160, 219 (1861) 3) F.C. Bowman & W.W. Scott, IEC 7, 766 (1915) 4) L.M. Kolhoff et al, JACS 55, 1454 (1933) (Scott's StedmethChemAnal, 5th edit (1939), p 644 (includes the proc for this method) 5) W.D. Treadwell & H. Vontobel,
F 19


Ferrous Sulfide (Iron Protosulfide), FeS; mw 87.92, blk hex metallic solid, sp gr 4.84, mp 1193 °C, bp decamp; insol in w, sol in acids. Can be prepd by fusing iron with equiv amt of sulfur. Used for generating hydrogen sulfide


Fertilizer Distributed by Explosives. W.O. Snelling obtained 3 patents (USP 1274343, 1308453, 1316005) for methods of distributing fertilizer by expls. The fertilizer in large lumps is mixed with the expl or packed in a container around a core of expl. Deton breaks up the lumps and distributes the expl thru the ground

Fertilizer Grade Ammonium Nitrate. See FGAN

Fertilizer Recovered from Explosives. AN in unneeded expls is recovered by leaching with water, adding peat to the solution and drying (Refs 2 & 3). When the expl contains perchlorate, the water is replaced by KCl soln which eliminates the perchlorate (Ref 1). The expl may also be agitated at room or elevated temp with hydroxides of alkali or alkaline earth metals (pref calcium hydroxide) with or without application of pressure (Ref 4) [See also Ammonium Nitrate, Fertilizer Grade (FGAN) in Vol 1 of Encycl, p A364]


Fascollzing of Shots. A nickel plating process for ballistic mortar projectiles by Fascol, Ltd, hence the name. The useful life of the mortar and the projectiles is increased


Feu. (Fr) Fire; firing

Feu d’artifice. (Fr) Fireworks

Feu d’artifice de guerre, (Fr) Military fireworks

Feu de canon. (Fr) Artillery fire

Feu grégeois. (Fr) Greek fire

Feu grisou. (Fr) Firedamp

Feu liquide. (Fr) See Fenian fire

Feu lorrain. (Fr) See Lorain fire

Feu prussion. (Fr) See Eigfall powder
FF-30. A std commercial ignition material for "Them 64C" consisting of the following compn: Ti 30 & Fe₂O₃ (red pigment grade 70% Ref: Tech Command, ArmyChemCenter, Maryland, "Development of an Incendiary Pellet", TCR-59 (May 1950)

FGAN (Fertilizer: Grade Ammonium Nitrate). See AMMONIUM NITRATE, FERTILIZER GRADE in Vol 1, pp A364-L to A367-L and also pp A359-R to A362-L

F.G. Powder. Fine grain Black Powder used in the 19th century in England as proplnt for smaller caliber cannons and as a bursting charge for shrapnel shells Ref: Daniel (1902), p 300

Fl (Figure of Insensitiveness) Test. See FL Test

Fiber or Fibre is any tough substance composed of threadlike tissue, especially when capable of being spun or woven. Fibers may be divided into animal (wool or silk), vegetable (cotton, hemp, flax, ramie, esparto, jute, sisal etc), mineral (asbestos, glass fiber) and artificial (Rayon, Nylon, Orloa, Vinyon, Saran etc)

All the vegetable fibrous materials are more or less suitable for the preparation of explosives (See Nitrocellulose, Nitroguite, Nitramine, etc) (See also Cotton, Vol 3 p C545ff)


Fickett Equation of State Based on Intermolecular Potentials. See Vol 4 of Encycl, p D277-R


Field Chronograph Test. See Vol 3, p C310-L, under CHRONOGRAPHs

Field Clearing with Dynamite or Other Explosives. This means the removal of stumps, boulders and rock ledges by the use of suitably placed and sized charges of Dynamite (or other explosives). Such variables as soil compressibility, hardness of the rock or wood, overall massiveness, etc make the writing of rules impossible. In general a single charge is placed in a hole under a lateral rooted stump; multiple charges are placed between the roots of a semi-tap rooted stump and fired simultaneously, electrically; tap rooted stumps may be drilled for one charge to remove only the upper portion, or dug around deeply on opposite sides for the simultaneous firing of two charges for total removal. Boulders are handled either by placing a charge underneath - snake holing, or on top covered with a layer of mud - mud-capping. Rock ledges are best handled by drilling, but the boulder methods will work too, preferably snakeholing


Fielder Explosive. A Sprengel type explosive, invented in Russia by Fielder, was prep'd just before use by mixing the liquid ingredient (fuel) with a solid ingredient (oxidizer). The fuel was a mixture of NB 80 & turpentine 20%,
whereas the oxidizer was a mixture of K chlorate 70% & K permanganate 30%
Refs: 1) Daniel (1902), 300 2) Thorpe, Vol 2(1912), 421 3) Davis (1943), 355
4) Pérez Ata (1945), 231

Fieldner, Arno C., Dr. (1882–1966). Pioneer US Gov't research scientist and internationally
known authority on coal and other fuels who died July 13, 1966 after an automobile accident. He
graduated from Ohio State University and began work as a chemist at the
BuMines at the time of its founding in 1910. During WWI he directed research on gas masks
and adsorbents for CWS. In 1942 he was named chief of fuels and explosives services at
BuMines, and in 1956, as chief fuels technologist. He retired in 1955

Field Parachute Drop Test for Fuzes. See Vol 4, p D1093-L

Field-Proof Gun. A special shot gun for taking
simultaneously the recoil and pressures at 1
inch and 6 inches from the breech. The velocity
and pattern can also be taken at the same time.
The gun weighs 50 lbs and is suspended 5 ft
below the supports; it is fired by means of a
pneumatic bulb in order not to disturb the gun.
The gun and support are shown in Fig F2

The "pattern" of the shot is determined by firing
at a whitewashed iron plate, generally at a
range of 40 yards. The marks of the shot
should be fairly evenly distributed, and about
2/3 rd of the shot should be within a circle
of 30 inches diameter

The penetration of shot can be measured
by firing under standard conditions at a number
of pieces of cardboard placed one behind the
other and counting the number of pellets that
penetrate different cards
Ref: Marshall 1(1917), 332 & 333

Field Samples of Permissible Explosives.
See Vol 3, p C376-R, under Coal Mining Explosives, Testing for Permissibility

Field Testing of Explosives. When unexploded
ammunition is found in the field, it is usually
required that it be destroyed or rendered inert.
It is necessary to know how sensitive the
charge is in order to know how to handle it.
This can be determined if the various expl
components are identified directly in the field;
it is advisable to carry a magnifier.

The following general characteristics of
expls sometimes help in identifying them:
1) Appearance, such as color, gives an indication
of the approx identification: TNT (buff or brownish), Picric Acid and Explosive D
(yellow), RDX and PETN (white). However,
since as many other expls are brown or yellow
in color, this method is not very reliable. The
question is further complicated if the expl is
dyed, a practice in some foreign countries
2) Method of loading, such as press- or cast-
loaded, might give some indication as to the
identity: TNT (cast), Tetryl (pressed), etc,
but it is not always possible to distinguish
the method of loading unless a magnifying
glass is used
3) National and functional use of the expl.
If the national origin of the expl and its
functional use are considered in conjunction
with the color and method of loading, it is
sometimes possible to correctly identify the
expl. For instance, if an American booster
charge is a yellow press-loaded compound,
one can be sure that it is Tetryl; white booster
charge can be either RDX or PETN. In the latter
case further identification is unnecessary be-
cause both expls are practically of the same
sensitivity. As PETN is slightly more sensi-
tive, it is safer to treat the expl as though
it were PETN
4) Sensitivity. In order to ascertain how care-
fully an expl has to be treated, it is necessary
to determine its sensitivity. This is especially
important in the case of primary and
initiating expls

The following Field Tests give an approx
idea of the sensitivity:
a) Remove a few particles of the expl by the
use of a long wooden or plastic spatula and
FIG F2
FIELD PROOF GUN
Table F3

Tests of Noninitiating Explosives

<table>
<thead>
<tr>
<th>Color of universal test</th>
<th>Color of ppt with</th>
<th>Color of test with</th>
<th>Color of test with</th>
<th>Color of test with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nessler's</td>
<td>Ethylenediamine</td>
<td>Diphenylamine</td>
<td>Thymol</td>
</tr>
<tr>
<td>TNT</td>
<td>(Insoluble)</td>
<td>Maroon</td>
<td>Colorless</td>
<td>Green</td>
</tr>
<tr>
<td>Tetrazyl</td>
<td>(Insoluble)</td>
<td>Red</td>
<td>Blue</td>
<td>Green</td>
</tr>
<tr>
<td>Picric acid</td>
<td>Yellow</td>
<td>Red</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>Explosive &quot;D&quot;</td>
<td>Yellow</td>
<td>Brown</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>Halexite</td>
<td>None</td>
<td>(No ppt)</td>
<td>None</td>
<td>Blue</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>None</td>
<td>(No ppt)</td>
<td>Deep blue</td>
<td>Green</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>None</td>
<td>Brown</td>
<td>None</td>
<td>Dirty green</td>
</tr>
<tr>
<td>PETN</td>
<td>(Insoluble)</td>
<td>None</td>
<td>Dirty green</td>
<td>Green</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>None</td>
<td>(No ppt)</td>
<td>Deep blue</td>
<td>Green</td>
</tr>
<tr>
<td>DEGN</td>
<td>None</td>
<td>(No ppt)</td>
<td>Deep blue</td>
<td>Brown</td>
</tr>
<tr>
<td>Nitrocellulose</td>
<td>None</td>
<td>Blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tritonal</td>
<td>(Insoluble)</td>
<td>Maroon</td>
<td>Colorless</td>
<td></td>
</tr>
<tr>
<td>Tetrytol</td>
<td>(Insoluble)</td>
<td>Maroon</td>
<td>Intense blue</td>
<td>Green</td>
</tr>
<tr>
<td>Picratol</td>
<td>Yellow</td>
<td>Brown</td>
<td>Maroon</td>
<td></td>
</tr>
<tr>
<td>Ednatol</td>
<td>None</td>
<td>Orange</td>
<td>(No ppt)</td>
<td>Maroon</td>
</tr>
<tr>
<td>Amatol</td>
<td>None</td>
<td>Brown</td>
<td>Maroon</td>
<td>Dirty green</td>
</tr>
<tr>
<td>Ammonal</td>
<td>None</td>
<td>Brown</td>
<td>Maroon</td>
<td>Dirty green</td>
</tr>
<tr>
<td>Pentolite</td>
<td>None</td>
<td>(No ppt)</td>
<td>Maroon</td>
<td>Dirty green</td>
</tr>
<tr>
<td>Trimite</td>
<td>Yellow</td>
<td>Red</td>
<td>(No ppt)</td>
<td>Orange</td>
</tr>
<tr>
<td>Tridite</td>
<td>Yellow</td>
<td>Red</td>
<td>(No ppt)</td>
<td>Orange</td>
</tr>
<tr>
<td>Black powder *</td>
<td>None</td>
<td>No change</td>
<td>Blue</td>
<td>Green</td>
</tr>
</tbody>
</table>

1 Color appears immediately.
2 Sometimes explodes mildly (puffs) upon addition of sulfuric acid.
3 Tests of dried water extract.

place on a hard surface (iron, cement, stone, etc). Hit a light blow with a hammer. If it detonates, treat very carefully, as it is a primary or initiating expl. If no expl occurs, take a new sample and repeat with a hard blow. No deton means that it belongs to the same class of expls as TNT and only normal care is necessary. Another good test is to place one grain of a sample in a small flat mortor and rub gently with a pestle. If the sample detonates, it belongs to primary or initiating expls

b) Place a small quantity of the expl on a non-combustible surface and insert the end of a safety fuse about 1 ft long. Ignite the end of the fuse and retire to a safe distance. If the expl detonates, it should be considered as a primary expl and treated accordingly.

5) Solubility and Color Tests. See the accompanying Table for data. Place 50 mg of the sample in a 5-ml beaker with 2-3ml of water and stir for 5 min before noting the color of the soln. Test the acidity with Universal pH indicator paper. Add a drop of Nessler’s reagent (to 5g of KI in a min of cold water add a satd. aq HgI₂ soln until a ppt forms; add 40 ml of 50% aq KOH, let settle, dilute to 100 ml with water, let settle and decant) and note color of ppt. Place 50 mg of sample in each of three depressions on a spot-test plate. To one add 2-3 drops of a 65-68% aq ethylene diamine soln, stir and note color of soln; to another add 3-4 drops of a solution of 1g diphenylamine in 100ml of concd sulfuric acid, stir and note color of soln after 1 min; to the last sample add 50mg of thymol and 3 drops of concd sulfuric acid, stir and note color after 5 min.

6) Melting point and range. If the above characteristics are insufficient, it is advisable to determine approx the melting point, but not in the case of primary or initiating expls such as MF, LA, LSt, etc.

Procedure:
a) Place a small quantity of the expl in a narrow test tube and attach a thermometer
by means of a rubber band in such a manner that the bottom of the tube and the mercury bulb are on the same level
b) Insert the lower part of the tube into a beaker containing light oil, heated by means of an alcohol lamp (or a Serno outfit)
c) Observe the temp at which the expl liquefies
d) Cool the bath until the expl completely solidifies
e) Heat the bath to about 5° below the mp, as previously determined, and remove the flame
f) Resume heating with a very small flame, allowing the temp to rise about 1°C per min, until the expl just begins to melt
g) Remove the beaker from the flame quickly and observe the temp closely. If the melting was completed without raising the temp, the expl may be considered as pure (and not a mixture) and the temp can be considered as the mp
h) If the expl does not melt completely, place the beaker on a small flame and raise the temp 1° above that previously observed, if the expl still does not completely melt, raise another 1° and so on until the expl completely liquefies

If the temp between the beginning and the end of the melting is more than 3°, the expl can be considered to be a mixture, and this interval is called the melting range

All the tests described above should be conducted with very small quantities of expl which should not be confined in such a way that fragmentation of the container can occur


Fiery Mines. Same as Gaseous Mines

Figure of Insensitiveness Test. See Fl Test

Figure of Merit is, accdg to Ref, gas volume times heat of explosion. If it is equal to 675 for TNT, for RDX it is 1162, Tritonal 792, Nitromethane 1133, Astrolite A-1-5 1600 & Astrolite G 1175


Note: Astrolites are liquid military expls developed by the Explosives Corp of America, Issaquah, Washington. Their cprms are based on Hydrazine

Filage (Étirage) des Poudres [French, literally meaning “Spinning (Drawing-out) of Propellants”]. This method used during manuf of French Smokeless Propellants (“poudres sans fumée”, also known as “poudres colloïdales”) is described by Pepin Lehalleur (Ref 1). It is similar to Graining, described by Davis (Ref 2) and briefly in Vol 3 of Encycl, p C399

In the Fr method, also known as “moulage”, the colloided NC, previously mixed in a kneader with other ingredients of propnt, is forced, by means of hydraulic pressure of about 300 kg/sq cm, thru slots (of different widths and thickness for each type of propnt), from which it emerges in the form of ribbons. They are then cut into strips of a length convenient for loading into the gun for which the propnt is intended. These propnts are known as “poudres lamellaires”. For the formation of tubular propnts (seldom used in France), the colloided mass is forced in the die into the space which surrounds a centrally fixed steel wire

Ref: 1) Pepin Lehalleur (1935), 298–300
2) Davis (1943), 302–04
3) P. Arribat et al, MP 32, 279–85 (1950)

Filite. An Ital Ballistite, manufd in the form of cords. It contd equal parts of NG & Collodion Cotton with 0.5–1% aniline added. It was brown in color and had density 1.6. It was a “hot” propnt which badly corroded gun barrels

Ref: 1) Gody (1907), 651
2) Marshall 1 (1917), 302

Filler. A material added to a product either to increase its bulk or weight, or to improve its props or appearance. In plastics, fillers are used to give the product certain desired
mechanical & electrical props, to improve internal stability, and to increase resistance to various service conditions. Some examples of fillers are as follows: wood flour, chopped paper (papier maché), palmetto, asbestos, chalk, cotton, mica, glass fibers, china clay, talc, graphite, metallic powders, metallic oxides & quartz
Ref: Kirk & Oehmer 10(1956), 799

Filler or Bursting Charge. The expl material which comprises the main chge in an expl loaded ordnance item
See also Charge in Vol 2, p C150-L
Ref: NOLTR 1111(1952), p G2

Filler or Bursting Charge of German Projectiles of WWll (Füllung or Füllpulver) (Fp or FP). See under German Military Explosives of WWll in this Vol

Filling of Bombs, Shells, etc. See under Loading of Ammunition

Film Bridge Initiators. Conductive films applied to surfaces of insulators by chemical precipitation or vacuum evaporation have been used to produce bridges which can be heated or exploded to initiate expl reactions. Since the initiation mechanism is complex, film bridges cannot be designed by computation. Typical complications include non-uniformity of film thickness and variations in conductive paths to the electrodes. Some experimental results have been obtained with a variety of film bridge initiators (See Ref 1), but the only type applied in standard fuzes has been the low energy graphite bridge type

Plugs for graphite bridge initiators are made by molding the plastic about a twisted pair of enameled wires, and then grinding the surface clean. This leaves a plastic surface with two metal islands separated by twice the thickness of the enamel. A droplet of colloidal suspension of graphite in water is applied over the point of closest approach of these islands to dry. Since both resistance and sensitivity are at least in part determined by the chance distribution of the graphite particles, item to item variation is great. Acceptable resistance range for Army items is 1000 to 10000 ohms, and for Navy 700 to 14000 ohms. Generally several hundred ergs of input energy are required for reliable initiation (Ref 2)


Filtration, Filter Aids and Filter Mediums.
Filtration is the separation of undissolved particulate solids from a mixture of fluid and solid. The separation is brought about by passage of the fluid thru a pervious septum (filter medium) in or on which the solids are retained. A driving force (gravity, vacuum, pressure, or centrifugal force) produces the flow. Filter aids may be added to the fluid before filtering to counterbalance the unfavorable characteristics of badly filtering materials

Filter Aids are porous powders added in small quantities to a soln or suspension to be filtered, in order to increase the efficiency of filtration. They are useful when handling suspensions of finely divided solids or of colloidal materials. The aid should not be much heavier than the liquids to be filtered, so that it will not settle immediately but will remain in suspension for a while. Kieselgur and paper pulp are the most widely used filter aids. Others are sawdust, charcoal, Fuller's earth, magnesia, salt, gypsum and some activated charcoals. The charcoals act as decolorizers at the same time

Filter Mediums are materials used for filtering, such as filter paper, filter pulps, cotton fabrics, cotton ducks, cotton twills, cotton chain, cotton batting, wool cloths
and felts, jute cloths, fibrous glass, nitrate
cotton cloths, human hair cloths, silk, nylon,
vinylon, metal fabrics, porous blocks (such
as carbon and graphite), aloxite, alundum,
silica, porcelain and granular beds.

Refs: 1) A. Weissberger, Ed., "Technique
of Organic Chemistry", Vol 3, 2nd edit (1956),
pp 607-786  2) Perry (1963), pp 19-54 to
19-86   3) Kirk & Othmer, 2nd Edition,
Vol 9 (1966), pp 264-86 (23 refs)

FILUP (Franklin Institute Laboratories
Universal Pulser). This instrument is used for
testing Electro-Explosive Devices (EED's)
(See in Vol 5 of Encycl, p E63-L). It supplies
constant current or constant voltage pulses
of varying magnitude & duration. It is also
capable of measuring EED's resistance and
functioning times and provides containment
for the initiator being tested. The instrument
is described in Ref 2 and a more recent version
is described in Ref 3.

Refs: 1) J.C. Kenyon, "No-Fire Level Test
of TADM Electro-Explosive Devices", Ordi-
nanice Missile Data Rept (1962), White Sands
Missile Range, New Mexico (DA Project
512-15-009)   2) C.T. Davey, "FILUP,
Instructions for Operation and Maintenance",
Franklin Institute Report FM-A2357-1,
July 1961, prepared for Picatinny Arsenal
under contract DA-36-034-501-ORD-3115RD
(AD-315 471)  3) C.T. Davey, "Operation
and Maintenance Manual for FILUP 3",
Franklin Institute Report FM-B2230, June
1965, prepared for NASA/Langley Research
Center under contract NAS 1-4062

Fineness. In order to determine if a sample
of NC is sufficiently pulped, the following
procedure is used:
1) Transfer a 10g sample of the dried NC (see
Drying of NC) to a 250ml beaker, add 100-
150ml water and mix by swirling the beaker.
2) Transfer the mixture to a 250ml glass or
rubber stoppered measuring cylinder, graduated
in 2ml divisions over a length of about 10
inches to the 250ml mark. Rinse the beaker
with several portions of water and transfer
the washings to the same 250ml graduate

3) Fill the graduate to about the 240 mark,
stopper and shake vigorously.
4) Remove the stopper and rinse it with a
stream of water from a wash bottle. Rinse
the inner wall of the cylinder in the same
manner until the volume in the cylinder is
exactly 250ml.
5) Replace the stopper and allow the cylinder
to stand undisturbed for exactly one hour
6) Read the volume in ml occupied by the
NC layer and consider this as the fineness
value. A value of 90±10 is usually considered
satisfactory.

Ref: US Spec JAN-N-244 (1945), p 11 (Now
MIL-N-244A (2) (Oct 1965)

NOTE: See requirements and tests g) under
Cellulose Nitrate Analytical Procedures in
Vol 2, p C122-L

Fineness of Grind (Degree of Dispersion).
The method intended to measure the "fineness
of grind" is described as Method 4411.1
(Sept 1, 1965) of Federal Test Method Stan-
dard No 141a. The apparatus consists of a
device known as the Hegman Gage.

See also Table 1 showing Comparison of
US, Tyler, British and German Sieve Series
in Vol 1 of Encycl, p A674.
The French "Fineness Test for Nitro-
celluloses" is described under the title
"Epreuve de finesse des coton-poudres" in
Vol 5 of Encycl, pp E108-R to E109-L

Finissage des Poudres. French for "Finishing
of Propellants". The term means the last
operations in the manufacture of propellants,
to make them ready for packing or for loading
in ammunition. The "finissage" operations
include lissage (smoothing), plombrage
(glazing or graphiting), mélangage (blending)
and sometimes bottelage (packing) (Refs 1,
2 & 4). The process is similar to that de-
scribed by Davis (Ref 3).

Refs: 1) Vennin, Burliot & Lécroc'h (1932),
508-600   2) Pepin Lehallier (1935), 306
3) Davis (1943), 305-06   4) J. Fauveau &
R. Delpy, MP 31, 161-66 (1949)
Fin Stabilization and Spin Stabilization.

Fin Stabilization is defined in Glossary (Ref 2, p 115-R) as the method of stabilizing a projectile, as a rocket, bomb or missile, during flight by the aerodynamic use of protruding fins.

Spin Stabilization is defined in Ref 2, p 270-R as the method of stabilizing a projectile during flight by causing it to rotate about its own longitudinal axis.

Accdg to Maj Hobart (Ref 3), the idea of fin stabilization is much older than spin stabilization. This is because the earliest weapons were smooth-bore and they could use finned projs, while spin projectiles required rifled weapons which were not invented until about 1500. The earliest fin-stabilized projectile was an arrow and then fireworks projs, which could be called rockets. The earliest projs fired from smooth-bore barrels of small arms or cannons were like balls and they did not have any stabilizing attachments. However, accdg to the description given in Milimet Manuscript of 1326, now in Christchurch, Oxford, the earliest cannon, known as pot de feu (fire pot) was fin-stabilized (See also Vol 2 of Encycl, p C26-L).

Maj Hobart further states that after 400 years of oblivion, the finned projectile has been reintroduced in the US in the flechette (qv). In the early 1960's this round was found to offer very considerable advantages.

The spinning of a projectile is produced by the engraving of the bullet envelope on the grooves of the rifling cut into the bore of the barrel. The rate of rotation depends on the steepness of the rifling spiral (usually expressed as one turn in x inches; it may be referred to in larger guns as one turn in x calibers, or the helix angle may be the reference parameter).

Maj Ohart (Ref 1, p 331) discussed stability and accuracy of fin-stabilized and spin-stabilized rockets. Accdg to him, spin-stabilized rockets are more accurate than the fin-stabilized ones. On pp 341 to 349 are described various fin- and spin-stabilized rockets.

Accdg to Maj Hobart (Ref 3, p 313), for a long-range weapon the spun projectile is superior to the fin-stabilized such as the "flechette", while for ranges up to 400 meters, the target effect is much the same, but the accuracy of the flechette depends entirely on launch conditions.

More discussion on this subject is given under "Flechette".

A good example of successful fin-stabilized rocket is the Faustpatrone described in this Vol Refs: 1) Ohart (1946), 331 & 341 to 349 2) Glossary of Ordn (1959), 115-R & 270-R 3) Maj F.W.A. Hobart, Ordn 57, 313-15, Jan-Feb 1973

FIRE [Feuer (Ger), Feu (Fr), Fuoco (Ital), Fuego (Span) and Onog (Russ)]

Merriam-Webster (1961) gives the following definition of fire as a noun: "The phenomenon of combustion as manifested in light, flame and heat and in heating, destroying and altering effects.

The term "fire" can also be used to mean: the discharge of firearms (as in heavy fire), to set on fire, to cause an explosion by lighting or ignition (fire a charge of explosive), to detonate a charge of Dynamite or other Blasting Explosive, to propel as from a gun (fire a projectile, fire a rocket), to feed the fire (fire a boiler), to take fire (damp BkPdr will not fire), to discharge artillery or firearms and many other uses, as for example in "fire" meaning discharge from employment.

The use of fire has been considered one of the basic elements of civilization along with tool making (frequently requiring the use of fire) and speech. Fire is generally used to provide either heat or light. Langhans (Ref 4) discusses the cultural and historical aspects of fire as a religious symbol, some aspects of the production of fire, and some early alchemical and scientific aspects, as well as theories of combustion. Greenwood (Ref 3) discusses fire as related to its fuels. Refs 1 & 2 are concerned with the heating effects of fire. Fire is considered under four topics: "liberated fire" (heating of objects), specific heat, latent heat (of changes of state), and "combined fire" (heat of reaction). Ref 2 is a fictionalized treatment of some aspects and effects of fire and includes an attempt to prepare charcoal as an ingredient for a subsequent preparation of BkPdr.
Fire Aboard USS Forrestal in 1967, during which the bombs started to explode 90 seconds after the fire began, thus killing the first wave of fire-fighters, brought to prominence the necessity of increasing the "cook-off" period in bombs to at least 5 minutes. This task was achieved at the US Naval Ordnance Laboratory, White Oak, Md, 20910 by the method briefly described in Expls&Pyrrots 3(3) (1970). See also Fire Resistant Coatings for Bombs in this Vol.

Firearm. Any weapon from which a shot is fired (discharged) by people, but the term is usually applied to small arms. The invention of firearms dates to about the 14th century Historical. See under Bullets, Historical, Vol 2, p B-324


Fire Balls. The origin & date of first use of fire balls are unknown. Davis (Ref 2) quotes from the book of Hanzalet Lorrain in 1630 on how fire balls are made:

Take a pound of sulfur, three pounds of saltpeter, half a pound of gun arabic, four ounces of orpiment; grind all together, and mix well by hand, and moisten with brandy and make into a stiff paste into which you will mix a half pound of ground glass, or of crystal in small grains, not in powder, which you will pass thru a screen or sieve. Then, mixing well with the said paste, you will form balls of it, of whatever size you please and as round as you can make them, and then you will let them dry. If you wish to have green fire, it is necessary merely to add a little verdigris to the composition. This is a very beautiful fire and thoroughly tested, and it needs no other primer to fire it than the end of a lighted match, for, as soon as the fire touches it, it inflames forthwith. It is beautiful in saluting a prince or nobleman to have such agreeable hand fire balls before setting off any other fireworks.

Reilly (Ref 1) describes a gray mixt made by mixing 7 parts of meal powder with 100 parts of sulfur, and is mostly used for the manuf of fire balls (used in war). These consist of twill bags, charged with compressed gray mixture, which is filled into them with the aid of spirit; they are fired by means of a composition fuse. Gray mixture mixed with antimony sulfide is used for torches.

According to Col Fisher (Ref 3) incendiary balls were built up around a core such as small iron shot. Customary procedure was first to dip the shot into a vat of liquid sulfur, then wrap the ball in oakum, repid, roll in fine powder, and wrap with wire. This process was repeated until the diameter of the ball corresponded to the caliber of the cannon. A variant of the spherical surface-burning incendiary was the elongated projectile made by kneading a warm incendiary mix over a crossed iron frame which extended to approx twice the length of the desired diam. Typical incendiary components were green pitch, fine & corned powd, oakum, tallow, and a small quantity of naphtha. A faze of fine powd was inserted in the nose to ensure ignition.

Adaptations of burning-type incendiaries to metal projectiles began to appear toward the end of the 15th century.

Reifs: 1) J. Reilly, "Explosives, Matches and Fireworks", VanNostrand, NY (1938), p 147
2) Davis (1943), pp 55–57
4) J.F.C. Fuller
Footnote

Fire Bombs. See Vol 4, pp D944-L to D948-L, under BOMBS AND BOMB COMPONENTS

Fire Bombs, Fillings. See Vol 4, pp D941-L to D944-L and Addn

Fire Control. The basic problem of fire control is concerned with launching a projectile from a weapon station (that may be moving) at a target (that may also be moving) so as to score a hit on the target. An element of probability enters the situation because during its flight the projectile is under the influence of natural phenomena outside the launcher’s control. The variable factor in fire control problems is the lead angle between the line of sight from weapon to target and the weapon line (direction in which the weapon is pointed). The lead is affected by target motion, forces acting on the target during flight, and jump of the weapon in firing

Firedamp. Grisou (Fr), Wetter (Ger), Grisu (Ital), Grisú (Span), Gremuchii gaz (Russ). It is a combustible gas found in coal mines and also the combustible mixture of the gas with air. Firedamp began as marsh gas when the vegetation in the primeval swamp was laid down and the formation continued thru the transformation to peat, lignite and coal. Coal seams still produce firedamp, the quantity increasing with the rank of the coal.

An analysis of 60 samples of firedamp from Belgian coal seams (Ref 1) showed
CH₄ 97, N 1.6, CO₂ 0.64, H₂O 0.019, H₂₂N₂ 0.047, C₂H₂ 0.53%. Such a gas can easily form expl mixtures with air and, if a source of ignition is available (See Firedamp Explosions), a serious expln can result. A firedamp expln can also stir up coal dust and set off a far more serious coal dust expln. (See Coal Mine Explosions and Fires, Vol 3, p C360
Ref: 1) J. Venter & P.S. Stassen, ButMinesInfoCirc 7670 (1953) & CA 48, 1003 (1954)
2) E. Lensel, RevMinérale 46(2), 102–15 (1964) & CA 64, 3254 (1966)

Firedamp Dynamite (Dynamite Safe Against Firedamp) or Permissible Dynamite (Permitted Dynamite (Brit), Dynamite-grisou (Fr), Wetterdynamit (Ger), Dinamite-grisu (Ital), Dinamita grisú (Span) and Predokhranitel’nyi Dinamit (Russ)). See in Vol 3, pp C444-R to C456-R under “Coal Mining Explosives, Permissible” and in Vol 5, pp D1603-L to D1604-R, under DYNAMITE; also Vol 1, pp A355-L to A356-R, under AMMONIUM NITRATE DYNAMITE

Firedamp Explosions. Firedamp may be ignited by the flame from an explosive (Ref 2) or detonator (Ref 4), by jets of compressed air (Ref 5), and by friction (Ref 6). Ignition of firedamp by expls is avoided by use of especially formulated expls called Permissibles. These expls usually contain inorg salts that absorb heat and thus cool the deton gases. The cooled gases in turn help to choke the flame of the firedamp (Ref 8). The salt may also inhibit chain propagation in combustion of CH₄ (Ref 1). NaCl seems to be the most effective additive for inhibiting firedamp ignition (Refs 1, 3, 5, 7, 8, 9 & 10). As little as 3% has a measurable
but inconsistent effect while 10–20% has a very definite effect. For best results the salt should be as fine as possible (Ref 9) (See also Coal Mine Explosions and Fires, Vol 3, p C360; Coal Mine Explosions, Measures for Prevention, Vol 3, p C364; Coal Mines, Determination of Firedamp and Coal Dust in Atmosphere of, Vol 3, p C367; Coal Mine Explosives, Testing for Permissibility, Vol 3, p C368; and Commercial or Industrial Explosives, Vol 3, p C434)


Firedamp-proof Detonators. Firedamp-proof detonators have not received the attention that firedamp-proof expls have, possibly because the expln of the detonator is lost in the immediately succeeding expln of the main charge. Treatment of the detonator charge in caps follows similar lines to treatment of Dynamites in the addition of cooling additives, such as salts or wax (Ref 1), BuOAc (butyl acetate) (Ref 2), or polycarboxylic acids, oxygenated polycarboxylic acids, halogen substituted polycarboxylic and oxygenated polycarboxylic acids, and the neutral and acid salts of these (Ref 4). Doubling the thickness of the Cu shell of a cap reduces the hazard of igniting firedamp and replacing the Cu with steel reduces the hazard even more (Ref 6). The hazard from an electric blasting cap depends on the nature, size and density of the cap charge. Hazard from short-delays is governed by the type of the delay charge and whether or not there is slag ejection.

Detonating Cord type materials have the PETN filler mixed with carbonates or salts of polycarboxylic acids or their halide or OH derivatives (Ref 3) or are sheathed in a NaHCO₃–NaCl mixture (Ref 7).


Firedamp-proof Explosives. Same as Permissible Explosives, described under the same Refs as listed under Firedamp Dynamite.

Firedamp Recovery. Firedamp is essentially the same as natural gas and has value as a fuel. Recovery is practiced in Europe both for safety purposes (firedamp removed from the mine is no longer an expln hazard in the mine) and as a by-product for economic reasons. Recovery by several methods is possible. Some of these are cross-measure borehole methods from working galleries, boreholes from roads outside the seam being worked, superjacent heading method, suction, pack cavity method and blowers (Ref 3).

Fire, Greek [Feu grégeois (Fr), Grecheskii Ogon' (Russ)]. It is described in Vol 2, p B166-L, under BLACK POWDER, but the spelling of inventor of fire was wrong. It should be, accdg to Andreev (Ref 2), Kalininikos

Refs: 1) Daniel (1902), 299(Feu grégeois) 2) K.K. Andreev, "Vzryv i Vzryvchatiye Veshchestva" (Explosion and Explosive Substances), VoyenIzdatMinistOborony, Moscow (1956) (Grecheskii Ogon')

Fire Hazards, Common. See under "Fires and Explosions in Industries" in this Vol

Fire Hazards, Uncommon. These are typically taken to be gases, solvents, and other chemicals that can burn readily or that can react with some other material to produce heat and so set themselves on fire. A few examples of such materials are Na, K, phosphides, concd acids and alkalies & ferro-silicon etc


Fire Protection, Industrial. See under "Fires and Explosions in Industries" in this Vol

Fire Resistance Tests. They include the tests described in Vol 1, pp XXII & XXIII, under "SENSITIVITY TO FLAME, HEAT, SPARKS, ELECTROSTATIC DISCHARGES, ETC." The following tests were developed at the USBuMines: a) Fuse Test b)Hemispherical Iron Dish Test and c) Red Hot Iron Test

Fire Resistant Coatings for Bombs. The length of time bombs can withstand the heat from a jet-fuel fire, before exploding, can be approx tripled. The technique is to paint them with an intumescent coating,.015 inch thick. When this coating is heated, it moves thru a phosphoric acid-carbon precursor stage to a decomposing ester, which tends to form water, carbon and nonflammable gases. Blowing agents swell a thick carbon foam which envelopes the object in a heat-resistant layer.

Temperatures were measured inside the casings of 750-lb bombs. 60 gallons of jet engine (turbine) fuel were burned in shallow pans underneath each bomb. Explosion temp about 400°F - was reached in approx 1/4 minutes inside the uncoated casing and slightly less than 4 mins in the coated casing. In fires aboard aircraft carriers, or in ammunition supply depots, the additional time before detonation could be of great value to firefighters. The extra minutes might be sufficient to pull the bombs out of the flames - or, if that is impossible, for nearby personnel to seek safety


Fire Resistant Textiles. Clothing in general and working clothes in particular should be as fireproof as possible in order to reduce the danger of their catching fire when approaching or coming in contact with open flame, sparks, dangerous chemicals, etc. Fabrics made from wool, silk and protein-like polymers are not very flammable, but all cellulosic materials (such as cotton, rayon, cellophane, etc) are.

Attempts to fireproof cellulosic materials date from the 4th century BC when vinegar was used as a fire-retardant for wood. From that time, nothing of importance was done until the beginning of the 19th century, when Gay-Lussac made some linen and hemp fabrics fire-resistant by dipping them in solutions of some salts, followed by drying. These salts were water-soluble and did not remain in fabrics after washing. Beginning about 1850, some retardants were introduced which remained in the fabric after washing (insoluble deposits). One of the most important improvements was made,
however, in the early 1930’s when mixtures of halogenated organics and insoluble metal salts and oxides were introduced. These retardants found extensive use during WWII. The latest development, which appears to offer more promise for future use, is based on the chemical combination of the fire retardant with the cellulose molecules.

Among water soluble retardants (nondurable type) may be cited: ammo bromide, ammo tungstate, Na vanadate, Li hydroxide, Na molybdate, K or Na hydroxide, ammo meta-vanadate, DiAmm phosphate & Zn chloride. Among the insoluble deposits (durable type) are: ferric oxide, stannic oxide, Mn dioxide & Pb monoxide.

Among chlorinated organo-metal oxide type may be cited the following mixture:
25 parts of "vehicle solids" (consisting of chlorinated paraffins 60%, plasticizer 20% & film-forming resin 20%) are stirred in a ball- or roller-mill with 25 parts of "dry solids" (consisting of Sb₂S₃ 35, CaCO₃ 20, color pigments 30, ZnO 5 & mildewcide 10) and the resulting mixture triturated with 50 parts of petroleum solvents. The fabric is dipped in this mixture and then dried.

In the fourth type of fire retardants, a chemical bond between the molecules of the fire retardant and cellulose should produce a finish that strongly resists the effects of laundering and weathering. Among such retardants may be cited cellulose-ammonium phosphate, cellulose-urea phosphate, cellulose-titanium complexes & cellulose-titanium-antimony finishes.

A very good description of fire-retardant textiles is given in Kirk & Othmer (Ref 7)

Tests for Fire-resistance and Flammability.

In the "fire-resistance test", also called "vertical burning test", a 12 x 2½ inch strip of fabric is suspended vertically so that the lower edge hangs just ¾ inch above the top of a gas burner (which has previously been adjusted to give a 1½ inch luminous flame). This means that ¾ inch of the fabric extends into the flame. After 12 seconds the flame is removed and, if the fabric continues to glow, the duration in seconds is noted, as well as the length of the charred area. Most specifications allow an after flaming max of 2 seconds and an average char length (10 strips) of 3½ inches, with a max of 4½ inches for any strip (Refs 7 & 8)

Flammability test, known as the AATCC or "inclined flammability test", was developed in the USA during WWII and is as follows:

A 6 x 2 inch strip of fabric, clamped in a rack inclined at 45° is exposed at its lowest part to the flame of a microjet burner for a period of 1 second. If the sample catches fire, the time of flame travel over 5 inches of the sample is used as an indication of the relative flammability of the fabric.

This method, as well as other methods of testing, are discussed in Refs 5 & 6


Fire Retardant Paints. Fire retardant paints are based on chlorinated rubber and chlorinated plasticizers with added SbO₃. These reduce the rate of spread of flames. Addn of NH₄H₂PO₄, PE, or dicyandiamide produces an "intumescent" or swelling paint that forms a thick insulating layer over the surface to which it is applied when exposed to flames.

Fire retardant paints do not control fires and are no substitute for an automatic sprinkler system. They are best used where the only hazard is exposed, combustible, interior finish materials or in isolated buildings where sprinklers will not be installed. The paint must be applied at the rate specified on the container; if spread thinner the proper
measure of protection will not be obtained


Fire Starter M1. Used in Pyrotechnics. See Vol 4, p D762-L

Fires in Coal Mines. See under Coal Mine Explosions in Vol 3, pp C360-R to C367-R

Fires and Explosions are described in pamphlet by H. Freytag entitled "Feuer und Explosionen", Arbeitsministerium Nordrhein-Westfalen, Zentralinstitut für Arbeitsschutz, Druck W. Bertelsmann, W. Bielefeld (1949)

Fires and Explosions of Ammonium Nitrate, Including FGAN (Fertilizer Grade Ammonium Nitrate). See Vol 1 of Encycl, pp A357-L to A363-R

Fires and Explosions in Industries (Prevention, Protection and Extinction). In order to have fire, there must be present a combustible material (such as wood, coal, fuel oil, etc), an oxidizing agent (such as oxygen, nitrates, chlorates, perchlorates, peroxides etc), and sufficient heat to start the fire. If buildings are constructed of wood or cardboard, they provide enough combustible material to start a fire

Fires may be started by one or several of the following so-called "common fire hazards": matches and cigarettes, rubbish (spontaneous ignition), locomotive sparks, mechanical sparks, friction, open-flame devices, heating appliances, electric wiring and equipment, static electricity and lightning. The primary object of fire prevention and extinction is to avoid loss of life and personal injury; the secondary objective is the protection of property

These problems are of particular importance in explosive, ammunition and propellant plants because a fire in these plants might be accompanied by an explosion with consequent loss of life and property

Refs: 1) R. Assheton, "History of Explosions", Institute of Makers of Explosives, NY (1930)
2) F. Shepperd, "Fire Chief’s Handbook", Case-Mann-Shepperd Pubg Co, NY (1932)
3) Interstate Commerce Commission Regulations, "Transportation of Explosives and Other Dangerous Articles by Freight," NY (1941) and Supplements
4) A. Pordage, Ed, "Chemical Fires and Chemicals at Fires", Inst of Fire Engineers, London (1943)
6) A.M. Cameron, "Chemistry in Relation to Fire Risk and Fire Extinction", Pitman, NY (1948)

Fires, Extinguishing (by Explosions). The extinguishing of fires by explosions is based on the mechanical action of the formed gases and on the blowing out of the flame. There is some application in oil and gas well fires

Ref: Yu. V. Mekker, KhimReferatZhur 1939, No 11, pp 130-31 & CA 34, 828(1940)
Fires — Radioactivity and the Detection of Fires. An electronic detector apparatus responds to changes in current flowing thru an ionization cell containing an α-particle source. The presence of smoke particles, fumes, or vapor in the cell will change the current flowing in the apparatus and activate an alarm.

Ref: M.E. Nahmias, MAF 18, 613 (1954)

Fires and Spontaneous Ignitions. Spontaneous ignition of combustible materials results from some substance reacting with light, air, water or other chemical to produce heat. If the heat is not readily dissipated, the temp rises in the substance and ignition is likely. Cotton rag containing linseed oil is the most common example. Fresh hardwood charcoal, hay, grain, feed and manure, wet sawdust, and finely divided metals including Fe, Co, Ni and U are subject to spontaneous heating.


Fireworks. [Feuerwerk (Ger), Feu d’artifice (Fr), Fuoco artificiale or Fuochi d’artificio (Ital), Fuegos artificiales (Sp), Feywerk (Russ)].

Fireworks are displays of colored lights, noise and smoke used on occasions of public celebration; also the devices used for such displays.

Fireworks are a part of the field of civilian pyrotechnics (Greek pyr, fire; techne, art); the rest of the field is railway fuses and torpedoes. Military pyrotechnics includes lights for signals and illumination, noise makers for training, heat sources, smokes, and some minor rocket effects. Many of the same formulas and devices are used in both fields with the military devices more studiously built.

The essential characteristic of these devices is that the mixtures used in them produce reactions that are exothermal, self-contained, and self-sustaining. Most fire-works are intended for immediate consump- tion and have little or no shelf life. The sale of fireworks to individuals not licensed to put on displays is forbidden in many parts of the USA for reasons of safety. See also Pyrotechnics.

Firing of Blasting Explosives. Blasting Explosives fall into two classes: low or deflagrating and high or detonating. Blasting Explosives are described in Ref 1, pp B202 to B211.

Low Explosives (such as Black Powder, described in Ref 1, pp B165-R to B177-R) are initiated by Fuses, Squibs and some Blasting Caps. High Explosives are initiated by Electric Blasting Caps, Detonating Cords (such as "Primacord" Bickford) and by Detonators.


Firing Composition 121. One of the mixes used by the Germans during WWII in igniters: Pb chromate 50, K chlorate 25 & silicon 25%.

Refs: 1) PB Rept 95613 (1947), Section U 2) PATR 2510 (1958), p Get 49-L
Primers, Military (US) (Table E9 on p E57 gives electrical characteristics and compas of explosive trains of Electric Primers XM65, 87, 88 and 89); Electric Squib, MK1, All-Purpose (Vol 5, p E59-L); Electro-Explosive Devices (Vol 5, pp E65-L to E64-L); Electro-Explosive Devices, Pulse Firing (Vol 5, p E65); Electro-Explosive Device, Thin Film for (Vol 5, p E68-L)

S. Odomo, "Information Pertaining to Fuzes", Vol 4(1964), Explosive Components has compiled a Table, "Electrical Detonator Data Sheets", showing electrical characteristics & firing times for various electrical detonators

See also Vol 5, p E38-L ff, "Electrostatic Discharges and Sensitivity of Explosives to Initiation By Them"


Firing Pin. In a mechanical fuze, contact sensing is converted directly into mechanical movement of a firing pin which in turn is driven into or against the first element of an expl train (primer). For the simplest solution to obtain ignition using this method, the forces on munition impact are used to crush its nose, thereby forcing the pin into the primer. In a base fuze, the pin may float in a guide thru which it moves during relative changes of momentum. The two types of initiation using these principles are stab and percussion.

If the pin punctures the primer case and enters a suitable expl charge, an expln can occur. This is known as stab initiation. The shape of the firing pin commonly used in the US is constructed as shown in Fig F3 (Ref 1). Common firing pin materials include both steel and aluminum alloys. Rear end of pin may be shaped in any way convenient for assembly. Alignment of pin with respect to primer and surface finish of pin are important and affect the sensitivity (Ref 2). Fig F4 shows a typical stab detonator. For more information on stab detonators, see Vol 4, pp D844-L to D846-L.

If the firing pin does not puncture the case, the initiation is called percussion. The difference in action is due to primer construction. In a percussion primer, the expl is backed up by a metal anvil (See Fig F5). For information about percussion detonators, see Vol 4, pp D852-L to D854-L. The firing pin dents the case and pinches the expl between case and anvil. A percussion firing pin that has a hemispherical tip (See Fig F6) gives greater sensitivity than a flat tip, but changing tip radius has little effect on primer sensitivity. For more information on sensitivity relationships with respect to cup, anvil, charge, and pin, see Ref 1. The effect of firing pin alignment on primer sensitivity indicates little effect if eccentricity is less than 0.02 inches. Above
this figure, sensitivity decreases rapidly


**Firing Range.** An area or site designated for firing practice. Also the distance from a target at which a gun can be fired with effective results, as in "he was within firing range"; this range is considered as a capability of the gun

Ref: Glossary of Ordn (1959), 117-R

**Firing Station, Guided Missile.** A self-contained electronic item which provides remote control of guided missile functions prior to and including firing. It may include an "emergency propellant shutoff system". This is a self-contained unit designed to instantaneously disable the propulsion system of a guided missile

Ref: Glossary of Ordn (1959), 117-R & 226-L

**Firing Systems.** A group of connected components arranged to permit detonation of a charge from a remote station. The system may be electric, nonelectric, or a combination of both. In air, the system may be a simple fuse that leads from a distant point to a blasting cap, and a match with which to light the fuse. Underwater the system may be a complex arrangement of electrical wiring, blasting caps, detonating cord, primacord primers and a blasting machine. In either case, the firing system transmits energy from the point of firing to the main charge to detonate it.

For underwater work, a combination system is recommended. Best results are obtained when the detonating cord is fed from the main charge to a point above the surface of the water. An electric blasting cap is then attached to the cord and connected to the blasting machine or other power supply. This combination gives positive results because all electrical connections are above water


**Firing Time.** A period of time required to fire a charge of explosive, propellant or pyrotechnic composition at various temperatures of heating or at various electric currents. The term is also applied to the period of time during which a weapon is fired (Ref 1)

In order to determine the "firing time" of an expl, propnt or pyro vs temp of heating, a few grains of sample are placed on the surface of preheated, and maintained at desired constant temperature, devices used for determination of melting point. One of such devices is Fisher-Johns Apparatus [described in Fisher Scientific Co, Pittsburgh, Pa, catalog (1970), p 640]; another is Maquenne Block (electrically heated metal block with holes for capillary tubes & thermometer)

Several other methods are listed by Reilly (Ref 1) for dem of time of deflagration or expl. Among them the method of
E. Berl & G. Rueff, described in Cellulose-Chemie 14, 43 (1933). Their apparatus consisted of a copper block, heated electrically with holes for test tubes.

The firing time test can also be conducted by immersing to a fixed depth in a bath of molten Wood's metal, (preheated to a desired temp and maintained constant) a metal Blasting Cap and a small sample of test of const wt, say 0.02g. The time required to deflag or explode is noted and the test repeated at various other temps of the bath (Ref 2, pp XVI & XVII). The lower is the temp of exposure the longer is the time required to deflag or explode a sample. For example, if an unknown sample required 12 mins to be exploded at 168°, the time could be 16 mins at 160°, 30 mins at 168°, 60 mins at 143°, 2 hrs at 139.5° and 5 hrs at 136°C. (Ref 1, p 83)

There are a few examples of "firing time vs electric current" listed in Vol 5(Ref 4), Table E3, p E28 for Electric Delay Detonators XM60, T65 & T68 and in Table E9, p 57 for Electric Fuze Primers XM85, 87, 88 & 89.

In Vol 2 of Encycl (Ref 3, pp B264-R & B265-L) is described "Bridge Wire Lag" and there is defined the term "Induction Period" (See also in this Vol "Firing Current Required to Ignite or Detonate an Initiating Device")


First Aid is defined as the immediate, temporary treatment given in case of accident or sudden illness before the services of a nurse or physician can be secured.

Every workplace should be provided with equipment and one or several persons who have received standard first aid training, for instance, from the American Red Cross or US Bur Mines.

If a plant maintains a full-time physician and nurse service, then the organization of first aid crews is not of such great importance as in small plants not having hospitals and located at some distance from any. In the latter case, it is advisable to have a well trained first aid crew and equipment.

(See also under Industrial Hygiene and under Toxicology)


First-Fire. In pyrotechnic devices, an easily ignitable compn between the fuse (or other igniter) and the main charge. The main charge is not easily ignited by the fuse alone. The same as Igniter Composition (See in Article on Pyrotechnics)

First Fire Compositions in Igniters. It can be a mixture of an illuminating compn with BkPDrr. Five examples are listed in Vol 4, p D759-R

First Fire, Ignition and Starter Mixtures Used in Pyrotechnics such as defined in Dr Ellem’s book are listed in Vol 4, pp D763 to D767 and in Tables F, G, H and I.
**First Fires, Igniters and Starters in Pyrotechnics.** Their definitions are given by Dr. H. Ellern in "Military and Civilian Pyrotechnics", ChemPubCo, NY (1968), p. 189. See Vol. 4 of Encycl. p D760-L


**Fischer-Tropsch, Ruhrchemie Synthesis** is a catalytic process developed at Kaiser Wilhelm Institut in Germany before WWII (Ref. 1) for the artificial production of mineral oil products (hydrocarbons). Essentially, the process consists of the following steps:

1) Water gas is obtained by the action of steam on glowing coal or coke

\[ \text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2 \]

2) Petroleum hydrocarbons are produced by heating CO + H$_2$ to about 200° at normal (or slightly increased) pressure in the presence of catalysts such as cobalt oxide etc. The following reactions take place:

\[ \text{nCO} + 2\text{nH}_2 \rightarrow \text{C}_n\text{H}_{2n} + \text{nH}_2\text{O} \text{ and} \]

\[ 2\text{CO} + \text{nH}_2\text{O} \rightarrow \text{C}_n\text{H}_{2n+2} + \text{nCO}_2 \]

The product obtained by the Fischer-Tropsch process has been called "Synthal".

**Note:** When zinc oxide catalyst is used, the resulting product is methanol.


**Fisher Melting Point Apparatus.** See under Melting Point Determinations and in Catalog of Fisher Scientific Co., Pittsburgh, Pa (1970), p 640

**Fission Bomb.** See Vol 1, p A499-L under Atomic Bomb

**Fission Reaction.** See Vol 1, p A501-L, under Atomic (or Nuclear) Energy

**Fitch & Reunert patented in 1884 BkPdr: contg starch.** It is listed in Vol. 1, p A171-R as Amidon (Poudre à l’)

**FI Test (Figure of Sensitivity Test) (Brit). An Impact Sensitivity Test devised about 1908 by Dr. G. Rotter at the British Government Research Establishment, Woolwich Arsenal. Important changes were introduced in the method in 1966 by Mordock and Wilby (Ref. 4). The original method and the modifications are described.**

The original FI expresses in terms of a standard expl the relative energies required to produce expls of equal degrees of completeness. A standard impact sensitivity apparatus is used with the impact area enclosed so that the volumes of gases generated in an expln can be measured as an indication of the degree of completeness of expln. Picric Acid (PA) is assigned a value of 100% which was the first "standard". Expls less sensitive than PA have FI's greater than 100:
TNT 120, DNT 175. Expls more sensitive than PA have values less than 100: MF 10, PETN 38 & RDX 64

In performing the test, a standard weight is dropped from a series of measured heights onto fixed volumes of the test and standard expls. Four samples are used at each height. The heights are increased until complete deton occurs. The percentage volumes of gas liberated at each height are plotted as ordinate against the heights as abcissa. The ratio of the areas under the curves for the test and standard expl is the FI (Refs 1 & 2)

In 1966 several changes in the procedure were introduced by Mortlock and Wilby (Ref 4). Instead of measuring expl at several heights, the new procedure measures the height at which there is a 50% probability of expln. If there is no expln at a given height the next drop is at an increased height. If there is a shot at a given height, then the next drop is at a lower height. From these heights the median height is determined by the Bruceton Up-and-Down Method (See Vol 3, p C376 for info on Up-and-Down Method). Usually 50 shots containing 0.03cc of expl are used, although up to 200 have been shot. Standard and test expls are fired alternately. M & W also replaced PA with RDX as the standard expl. PA was an unsatisfactory standard because it showed day-to-day variations in behavior that seemed to be related to the humidity. RDX was assigned a value of 80 to give results consistent with previous work. In general the changes in procedure give an exact knowledge of the behavior of an expl at one impact distance while the older procedure gave less exact knowledge of behavior at several heights.

The Rotter procedure and its modification, as described, give no information as to the nature of the reaction that is taking place in the expl, but show only that a certain amount of decomposition has occurred. An impact test is used as a guide to industrial handling practices and it is useful to know if gas is produced by a deton or a burn. A material that burns is likely to be safer than one that detonates. In 1954 Moore and Pape (Ref 3) pointed out this need and devised a remedy. They devised a slit and mirror arrangement under the anvil that permitted photography of the duration of light emitted by the decomposing expl. From this information slow burns, fast burns, and deton could be distinguished and handling hazards more accurately evaluated


Five-Foot Drop Test. One of the field tests to check the safety and operability of a fuze after mishandling. It is briefly described in Vol 4, p D1093-R

FIVOLITE (2,2,5,5-Tetramethylcyclopentanol Pentanitrate or Nitropentanol)

\[ \text{CH}_2\text{C(CH}_2\text{ONO}_2\text{)}_2 \]

\[ \text{CH}_2\text{C(CH}_2\text{ONO}_2\text{)}_2; \text{mw 431.23, N 16.24%, OB to CO}_2 \text{ -55.3%; crysts, mp 91-2°, sp gr 1.57. It was first prep and patented in 1929 by Friederich & Flick (Ref 2). Accdg to Blatt (Ref 5), cyclopentanone is condensed with formaldehyde to form the ketone which is reduced with Cu chromite to secondary alcohol (pentanol) ( mp 97.5°). This is followed by nitration with mixed nitric-sulfuric acid at 3° to Pentanitrate}

Following are its props as listed in Refs 2, 3, 4, 5, 6 & 7:

Detonation Velocity: 5060m/sec at d 0.75 & 7360 at d 1.57

Fi (Figure of Insensitivity) > TNT & <RDX
Heat of Combustion at C_v 1149.9kcal/mol
Heat of Explosion 1035kcal/kg
Heat of Formation +144.3kcal/mole
Impact Sensitivity with 2kg weight 26cm for 3/6 expls, vs 70cm for TNT
Power by Ballistic Mortar Test – 151% TNT
Power by Trauzl Lead Block Test 160% TNT
Stability at 100° by Abel Test - 8 mins
No info at our disposal about uses of Fivonite
Refs: 1) Beil, not found 2) W. Friederich & K. Flick, GerP 509118 (1929) & CA 25, 819 (1931); USP 1962065 (1934) & CA 28, 4910 (1934) 3) V.L. Wöhrle & J.F. Roth, SS 29, 332-33 (1934) 4) Davis (1943), 285-86 5) Blatt, OSRD 2014 (1944) 6) ADL, Pure Expl Compds, Part 2 (1947), 224 7) Urbanski 2 (1965), 201

FIVONITE (FY) (2,2,5-Tetramethylcyclopentanone Tetranitrate, called also Nitropentanone or p 9)
\[
\text{CH}_2\text{C(CH}_3\text{)}_2\text{ONO}_2\text{CH}_2\text{C(CH}_3\text{)}_2\text{ON}_2\text{CO}_{\text{2}}
\]

CH_2C(CH_3ONO_2)CH_2C(CH_3ONO_2) <br>
CH_2C(CH_3ONO_2)CH_2C(CH_3ONO_2) <br>
CH_2C(CH_3ONO_2)CH_2C(CH_3ONO_2) <br>

Mw 384.22, N 14.58%, OB to CO_2 -45.8%; wet crystals of 1.611, cast of 1.590, both at 20°, d of liq 1.499 at 30°; mp 68-70° (Blatt), 74° (Davis). It was first prepared and patented in 1929 by Friederich & Flick (Ref 2). Accord to Blatt (Ref 5), it is prepared by condensation of cyclopentane with formaldehyde in a hydroxide solution at pH 9 to furnish tetramethylcyclopentanone in 95-100% yield. This is followed by nitration with 98.5% nitric acid and the resulting crude product is stabilized by melting under water, adding Na carbonate to alkalinity, rinsing with water and drying. Yield 93-95%. The polymorphic form is obtd in the form of monoclinic prisms by crystallizing Fivonite from acetone-alkol. The crystals are stable at RT

Following are expl and other props, as listed in Refs:
Brisance by Plate Denting Test, 112% TNT for pressed FY at d 1.54 (vs TNT at 1.55)
Deflagration Temperature, 265°
Detonation Velocity, 7292m/sec at d 1.57; 6815 at d 1.44
Explosion Temperature. Accord to OSRD 1767 it does not explode below 360° when placed on Wood's metal surface, while accord to OSRD 1985 it explodes at 285°
FI (Figure of sensistiveness), 62% PA
Heat of Combustion, 1093.5 kcal/mole
Heat of Explosion, 820 kcal/kg
Heat of Formation, +166.3 kcal/mole
Hygroscopicity at 25°C, gains 0.22% at 100% RH (Relative Humidity)
Impact Sensitivity by Brucon No 3 Apparatus, 50% positive in brass cups with 5kg weight at 90cm drop, vs 50cm for RDX
Power by Ballistic Mortar Test, 127% TNT Power by Trauzl Lead Block Test, 129% TNT Rate of Detonation. See Detonation Velocity Rifle Bullet Test. In 7 trials conducted in Canada with charges placed in steel pipe nipples - 5 passed, 1 detonated and 1 partially detonated
Stability (Thermal) at 100°, not acid and no expln in 300 mins
Stability at 135°, acid in 5-60 min and no expln in 300 mins
Storage (Surveillance), no apparent change in stability after 3 months storage at 50°
Thermal Stability. See Stability (Thermal)
Toxicity. In laboratory work no headaches or skin disorders were observed during 5 months
Vacuum Stability at 100°, 5-10cc gas evolved from 5g sample in 48 hrs
Velocity of Detonation. See Detonation Velocity
Uses: Being a HE and good plasticizer for NC, it is suitable for use in some expl and proplnt mixtures
Following mixtures are known:
FY/EDNA-50/50, called EDNATION (described under Ethylenedinitramine in this Vol, p E238 if
FY/PETN-50/50 - mixture of FIVONITE with PETN, known as PENTAFIVE (will be described under P's)
FY/RDX-50/50, known as CYCLOFIVE
(See Vol 3 of Encycl, p C594-L
Fixed and Semi-fixed Ammunition and Their Comparison with Separate-Loaded Ammunition are given in Vol 1, p A385-L, under AMMUNITIIONS AND WEAPONS OR ARMS. Some illustrations are given in Vol 2, pp C74 & C75 under CARTRIDGE, AMMUNITION and in Vol 4, pp D777-R to D792-R

Fixed and Semi-fixed Ammunition, Rounds of.
Round or Complete round of fixed artillery ammunition means that cartridge with propellant and loaded shell are all in one unit.

In Vol 4, pp D777-R to D792-R the following fixed and semi-fixed rounds are described and Figs are given:

37mm HE-T, SD (High-Explosive-Tracer, Self-Destroying), Fixed Round (Fig 33, p D778)

40mm HEI-T, SD (High-Explosive-Incendiary-Tracer, Self-Destroying), Fixed Round (Fig 34, p D778)

75mm HE-T, M349 (High-Explosive-Plastic-Tracer), Fixed Round, is described in conf TM9-1300-203-1 (1967)

75mm AP-T, M338A1 (Amor-Piercing-Tracer) Fixed Round, (Fig 35, p D779)

75mm APC-T, M61A1 (Amor-Piercing-Cap), Fixed Round, (Fig 36, p D780)

76mm Canister, M363, Fixed Round (Fig 37a, p D781)

76mm HVAP-DS-T (Hypervelocity-Amor-Piercing, Discarding Sabot-Tracer), Fixed Round, (Fig 37b, p D782)

90mm HE-T, T142 (High-Explosive, Plastic-Tracer) is described in conf TM9-1300-203-1 (1967)

90mm APC-T, M82 (Amor-Piercing-Cap-Tracer), Fixed Round (Fig 38, p D782)

90mm HEAT, M348A1 (High-Explosive-Antitank), Fixed Round (Fig 39, p D783)

90mm HVAP-T, M332A1 (Hyper-Velocity-Amor-Piercing-Tracer), Fixed Round (Fig 40, p D784)

105mm APDS-T, M392A2 (Amor-Piercing, Discarding Sabot-Trapier), Semi-fixed Round (Fig 41, p D784)

105mm HEAT-T, M455, Semi-fixed Round (Fig 42, p D785)

105mm HEP-T, M327, Semi-fixed Round is described in conf TM9-1300-203-1 (1967)

105mm HE, M1, Semi-fixed Round for Howitzer (Fig 43a, p D785)

105mm HE, RA, XM548 (High-Explosive, Rocket Action), Semi-fixed Round (Fig 43b, p D786)

105mm APERS-T, XM546 (Anti-personnel-Tracer), Semi-fixed Round (Fig 43c, p D787)

152mm HEAT-T-MP, XM409E3 (High-Explosive-Antitank-Multipurpose), Fixed Round for Gun Cannon, M81 (Fig 44a, p D788)

152mm TP-T, XM411E3 (Target Practice-Tracer) Fixed Round (Fig 44b, p D789)

57mm Canister Fixed Round T25E1 for Recoilless Rifles (Fig 45, p D790)

75mm HEAT-T Fixed Round for Recoilless Rifle (Fig 46, p D790)

90mm APERS Canister Fixed Round XM590 Series for Recoilless Rifles (Fig 47, p D791)

105mm HEAT Fixed Round, M341 for Recoilless Rifles (Fig 48a, p D791)

106mm HEAT Fixed Round, M344A for Recoilless Rifles (Fig 49, p D792)

Fixed Round of Artillery Ammunition, Explosive Train in. See Vol 4, p D839 and Fig 1-21b

Fixed and Semi-Fixed Ammunition: Testing and Surveillance. The following description is taken from the "Safety and Storage Manual for Explosives and Ammunition".

These types of ammunition are usually divided into lots varying from 5000 to 25000 rounds

Packing. Rounds of ammunition are usually packed in wooden boxes, with or without metal liners, or in wooden boxes with each round in airtight metal or fiber container.

Handling and Shipping should be done according to regulations set forth by the ICC. Storage. Fixed and semi-fixed ammunition is usually stored in "Magazines for Ammunition" (qv) but is also allowed to be stored in other magazines, such as those designed for smokeless propellants, explosives, primers and fuzes. The boxes should be piled according to the Ordnance Dept Regulations and no loose rounds of ammunition should be stored. All magazines should be provided with good ventilation.
Maintenance. This includes derusting, repainting, repairing packing boxes and repacking whenever necessary. The same instructions should be followed as given under "Smokeless Propellant, Maintenance".

Surveillance. This includes a visual examination of all boxes in which ammunition is packed, and a detailed examination of at least 5 rounds taken from two or more boxes to detect signs of rust, corrosion, exudation, projectiles loose in cartridge case etc. In addition to this, a representative sample of powder has to be taken from each lot, once a year, and subjected to the same tests as Smokeless Propellant: Methyl Violet, 65.5°, Surveillance and 134.5° Heat Tests, as described under these tests, and every three years a representative sample is taken from each lot for ballistic (firing) tests.

Sampling.
1) Select one round of ammunition at random from each of three boxes which are representative of the lot. Remove these rounds from the magazine and carefully withdraw the projectile, using a barricade in case of fixed ammunition.
2) Weigh and record the amount of powder in each cartridge case, blend carefully and spread on a clean cloth for examination. If no signs of deterioration are noted, take a sufficient sample for all the stability tests and destroy the rest.
3) If the sample shows signs of deterioration, as evidenced by the presence of grains with a yellow or orange discoloration or spots, treat it in the same manner as described under "Smokeless Propellant, Sampling".

Examination of Projectile consists in removing the booster (behind a suitable barricade and by means of a special device). If the booster cup is found to be corroded or rusty, or if the charge shows exudation, the shell should be salvaged or renovated. If the inside of the projectile is satisfactory, the nose of it should be closed with a suitable adaptor, or an iron or steel plug, and saved.

Renovation and Salvage. Ammunition which has deteriorated to such a stage that replacement of the fuzes, boosters, shell charges or propelling charges is necessary, has to be subjected to either "renovation" (qv) or "salvage" (qv).

Destruction. Fixed or semi-fixed ammunition rarely deteriorates to such an extent that it must be destroyed rather than salvaged or renovated. It may be necessary, however, to destroy loaded shells, such as those which are fused and too dangerous to unload. In this case, instructions given under "Separate Loaded Shell, Destruction" should be followed.

If the propelling charge becomes deteriorated, it has to be removed from the cartridge and burned as described under "Smokeless Propellant, Destruction".

Safety Precautions. Fixed and Semi-fixed ammunition should never be dropped, rolled or thrown, and as long as this is observed, there is little danger in handling it.


Fixed Particle Size and Shape Explosives were prepared for an investigation of the effect of particle size on detonation properties of compressed charges. Crystalization solvents and techniques were developed for close control of particle size for TNT, PETN, NGu and AmmPicrate.

Ref: G.A. Cave, N.J. Kotingger, and J.D. McCaleb, IEC 41, 1286–90 (1949) & CA 43, 6415 (1949)

Fk. German abbr for Flak which means "Flieger Abwehr Kanone" (Anti-aircraft Cannon)

Ref: Glossary of Ordn (1959), p 118-L & R
Flicking is the term for continuous solidification of molten material. Batch solidification is called casting. The types of apparatus as described in the ref are:

1) Table flaker — a flat metal sheet with turned up edges and jacketed on the under side for coolant flow. It is used for $1/2$-1 inch thick slabs

2) Vibrator type — a tray in which the bottom and one end curves up gently to be level with the top edges of the sides. An attached vibrator breaks up the solid and shakes it over the curved end of the tray to a discharge conveyor. Cakes may be up to 3 inches thick

3) Belt type — a metal belt floated on water receives the molten material which breaks into flakes as the belt turns down over the return roller at the discharge end. The cake is usually from 1/8 to 5/8 inch thick. Thicker cake may require use of a top belt for addn cooling

4) Rotating drum — single and double drum models are made. In either case the internally cooled drums turn thru the molten material picking up a layer that is flaked as it is scraped off by a doctor knife (or knives) into a discharge conveyor. Double drums are counter-rotating and the knives and discharge conveyors are between the drums. Cake may be from 1/64 to 1/4 inch thick

5) Rotating shelf — a vertical series of rotating annular tables carried by a central column that supplies coolant to the under side of the tables. One of two side columns supplies molten material to the trays and the other column carries removing knives and conveyors to remove the solid

A brief description of a single-drum flaker is given, together with Fig 6, on p D1560-L of Vol 5 of Encycl and of a double-drum flaker, together with Fig 7, on the same page

Ref: Perry (1963), p 11:42-3

Flame. Acedg to the Encyclopedia Britannica (1964) 9, 413–16, flame, as a phenomenon of the physical world, is generally understood to be burning gas. Its prerequisite is the formation of an explosive mixture, eg firedamp and air. If such a mixture is ignited (by spark or small flame), combustion spreads from the ignition source to the adjacent layer of the mixture, each point of the layer serving as an ignition source for the next adjacent layer. Thus, a combustion wave (flame front, combustion zone) is formed which propagates thru the gas mixture leaving behind hot, burned gas. The mixture propagates a flame only above a min and below a max % of gas (lower and upper limits of flammability, respectively). For firedamp the limits are $4\%$ & $15\%$, respectively

The wave travels at some definite velocity (burning vel) against the unburned mixture. Velocity depends on the composition of the mixture being zero at the limits and at a max at some intermediate composition (eg $9.5\%$ for firedamp). There are three types of flame:

- **Diffusion Flame.** When a slow stream of fuel gas flows from a tube into the atmosphere, air diffuses across the boundary of the stream and forms an envelope of exo mixture around a core of gas. The core decreases in height until it disappears at some distance above the tube. It thus assumes the shape of a cone. On ignition, a flame front spreads thru the mixture and stabilizes itself around the cone of fuel gas. The hydrocarbons in common fuel gases “crack” to form free C & H. The shell of carbon-bearing gas so formed gives such flames their luminosity

- **Turbulent Jet Flame.** When a gas stream issues from an orifice above a certain critical velocity, it breaks up into a turbulent jet that entrains the surrounding air. The flame of such a jet consists of random patches of combustion and no cohesive combustion surface exists

- **Flames of Streams of Explosive Mixtures.** From some point of ignition, a combustion wave spreads out until it forms a continuous surface over the whole cross-section of the stream. The flame front is shaped by relative values of burning velocity and gas velocity. If burning velocity exceeds gas velocity, the flame flashes back; if the burning velocity is less than gas velocity, the flame blows off into the atmosphere and becomes extinct. The flame establishes itself when the velocities are equal
Flame of Explosion. Nearly all expls are accompanied by a flame, varying in temperature, color, duration and size. In many cases, the appearance of flame is undesirable and it is necessary to suppress it completely or to diminish either its brightness or its size and temperature. For instance, when firing cannon it is desirable that the flame or flash not be so bright and intense as to be visible to the enemy. On the other hand, when shooting expls in fiery coal mines, the brightness of the flame is of no importance, but it is necessary to have the flame sufficiently cool and of short duration so as to eliminate the danger of it igniting the firedamp.

The problem of the flame of coal mine expls was investigated by Aguillon (1880), Mallard & LeChatelier (1888), Bicheli (1899), Wilkoszewski (1907), Will (1909), Dautruche (1910), Taaffanel & Dautruche (1912), Taaffanel & LeFloch (1913), French Investigating Committee (Commission des Substances Explosives), Naoum, Kast, Selle, Berthmann, Beyling, Schultz-Rhondorf, Schmerber, etc.

The following is the résumé of their conclusions:

1) The duration of the flame is as important as its size and temperature.
2) There is a certain degree of delay in ignition, or a certain period of high temperature required to cause ignition of firedamp, and expls with short duration of flame (such as most of the brisanent expls) would not ignite the firedamp even if the temperature of the flame is above the flash point of the firedamp. However, if the velocity of detonation of such expls is very high (say above 7000 m/sec), there is danger that a sudden compression of the surrounding air, caused by the detonation, might raise the temperature above the flash point of the firedamp and cause an expl.
3) The expls with long, durable flame (as Black Powder) almost always ignite the firedamp, even if the temperature is comparatively low.
4) The larger the charge of an expl, the greater the length and duration of flame, and therefore it is important to establish a certain maximum charge (charge limit) for each expl used in fiery coal mines.
5) The flames from permissible expls have shorter duration than those of other types and that is the main reason why they are safer to use; however, if the charge limit established for these expls is exceeded, there is danger of igniting the firedamp.
6) The temperature of the flame is also of great importance and most countries have established a certain max temperature. Mallard and LeChatelier thought that the max should be 2200°, but the French Investigating Committee (Commission des Substances Explosives) lowered this limit to 1500° for "couche" expls (permissible in coal seams) and 1900° for "mèche" expls (used for blasting accompanying rock).

One of the best methods for lowering the temperature without reducing the efficiency of an expl is to incorporate in the expl a large proportion of AN (Ammonium Nitrate). Na or K nitrates or chlorides are also effective.

7) The photographs of flames produced by mining expls, taken by Laffitte, showed that there are three classes of flames: a. Primary flames, due to reactions taking place within the borehole, b. Secondary flames, due to reactions in the gases outside the borehole but without the assistance of the air, c. Tertiary flames, due to the interaction of the oxygen of the air with the combustible gases from the expln. These flames often arise when the gases impinge on the walls of a shaft. It is only recently that the existence of secondary flames has been noticed. Previous investigators, such as Bicheli, Will etc, believed that there were only primary and secondary flames; their "secondary" corresponding to what is now termed "tertiary".

The same phenomenon is observed on firing cannon and the flame which is produced on contact with the air is sometimes called afterglow. The "afterglow", which is undesirable because it might indicate to the enemy the position of artillery, may be partly or nearly completely suppressed by the addition of a few percent of alkali salt (or other flash reducing compound) to the propellant (See Flash Reducing Agents).

8) As the result of Laffitte's experiments,
Bichel came to the conclusion that, in order to judge the safety of an expl, it is important to know the ratio of the time of detonation of the charge to the duration of the flame, which he called after-flame ratio (Ref. 1, pp 596-97).

Following are some of the results of Bichel’s flame measurements using a 100g sample of expl:

11) As there are many factors contributing to the flammability of firedamp by the flame of expls, most countries test the expls intended for use in fiery mines in special testing galleries in which the actual conditions existing in mines are simulated as nearly as possible (See Vol. 3 of Encyc., pp C368 to C378-L).

<table>
<thead>
<tr>
<th>100g of Explosive</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time of Detonation (seconds)</td>
<td>Duration of Flame (seconds)</td>
<td>Length of Flame (mm)</td>
<td>After-flame Ratio (Item 1 divided by Item 2)</td>
</tr>
<tr>
<td>Black Powder</td>
<td>.0000233</td>
<td>.077</td>
<td>110</td>
<td>1:330</td>
</tr>
<tr>
<td>Blasting Gelatin</td>
<td>.000011</td>
<td>.0097</td>
<td>224</td>
<td>1:882</td>
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<td>Guhr Dynamite</td>
<td>.0000134</td>
<td>.0083</td>
<td>228</td>
<td>1:620</td>
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<td>Gelignite</td>
<td>.0000119</td>
<td>.0012</td>
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<td>.0000019</td>
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<td>1:1049</td>
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<td>1:15</td>
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<tr>
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<td>.000508</td>
<td>.0033</td>
<td>40</td>
<td>1:6.5</td>
</tr>
</tbody>
</table>

Table F4

**Note:** The safer the expl from the point of view of firedamp ignition, the larger is the “after-flame ratio” and the lower duration of flame and its length (See Donarite and Carbonite).

9) Another factor which might contribute to the length, duration and temperature of the flame is the density of the expl. The higher the density, the higher is the velocity of detonation and temperature of the flame and the shorter is its length and duration. For this reason, permissible expls are made with very low density.

10) Other things being equal, an expl with a high velocity of detonation may be expected to give a flame of less duration than a slow one. But a very high vel of deton is undesirable in a coal mining expl, because it is liable to ignite firedamp by the rise of temp caused by the sudden compression (Ref 1, p 596)

*Refs:* 1) Marshall 2(1917), 596-605
2) Naqin, NG(1928), 384-85
3) Vennin, Burlot & Lécorché(1932), 228-35
4) Stettbacher(1933), 65-8 & 245-48
5) Pérez Am(1945), 125-29 (Caracteras de la llama de la explosion)
7) R. Steinberger, IEC 48, 766-68(1956)(Flames from nitrate esters; a review of recent work)
9) M.G. Saunders & A.G. Smith, JApplPhys 24, 115-17(1956)(Phase contrast observations in flames)
11) H. Selle, Explosivstoffe 8, 9 & 195-204(1960)(Investigations on flame
Some other investigators proposed quenching the flames using some nonexplosive dusts, such as stone dusts, dust of various inorganic salts of K (Ref 3). Dufrasne et al (Ref 4) proposed using K oxalate and claimed that 400 mg per liter of air was sufficient to extinguish a flame. Still better results were claimed to be obtained with a mix containing 30% K oxalate with 70% Na bicarbonate, because the amount required was only 200 mg per liter of air. The value named by Dufrasne et al determined the “pouvoir” for 250 substances (Refs 4 & 5). Extinction of flames is also discussed by Lewis & von Elbe (Ref 6).

Refs: 1) C.A. Thomas & C.A. Hochwalt, IEC 20, 575–77 (1928) 2) R.N. Pease, JACS 51, 1839–56 (1929) 3) W.P. Joriassen et al, Rec Trav Chim 52, 403–12 (1933) 4) Ch. Dufrasne & M. Geman, CR 207, 1221 (1938) 5) Ch. Dufrasne et al, CR 236, 164 (1953) 6) B. Lewis & G. von Elbe, "Combustion, Flames and Explosion in Gases", 2nd Edn, Academic Press, NY (1961), 322–23 (Dust quenching occurs at a critical value of the surface area of the dust per unit vol of the suspension, and depends on the nature of the salt. Better results are obtained with salts having a mp under 200°. Alkali halides are better than carbonates, potassium better than sodium, fluoride better than iodide and better than chloride. If the dust concentration is high enough, even detonation waves can be extinguished).

Flame Duration and Length. See Flame Length and Duration.

Flame, Extinction of. Flames of any kind are very dangerous, especially if they come in contact with some explosive or highly combustible materials. When a flame comes in contact with an expoxy gas mixture with air (like firedamp in coal mines), the expoxy might be propagated a long distance unless some precautionary measures are taken.

Sprinkling of water is not always effective, but the extinction improves if some inorganic salts (such as chlorides, carbonates, acetates or phosphates) are in water, as was proposed by Thomas & Hochwalt (Ref 1). Pease (Ref 2) proposed coating the walls in fiery coal mines with K salts.

In order to judge the approx length and duration of flame, Wilkoszewski, Will, Bichel, Kast, Naoum and others (Refs 1–6) photographed, at the beginning of this century, various explosions, using ordinary cameras and films. Such photographs did not yield as useful data as was hoped. Although it was easy by such methods to distinguish between expoxy produced by coal mining expoxy and brisant expoxy, it was not possible to draw conclusions as to the relative safety of different coal mining expoxy. One reason for this was that the films available at that time were not sensitive to infra-red rays.
emitted by comparatively cool flames which are, however, quite capable of igniting firedamp.

More recent methods of photographing flames include the so-called "Schlieren-Method" and the "Motion-Picture Camera Method" using films sensitive to infra-red. These methods are described in Refs 7-9 and the definition of "Schlieren-Method" is given in Vol 2 of Encycl, pp C15-R & C16-L. The motion picture cameras are similar to those used in the movie industry (Ref 8).

In Vol 1, p XII are listed several flame tests (including 5 refs) and among them the Bureau of Mines Test, described in USBur-Mines Bull 346 (1931), p 67.

Belgrano (Ref 12) described the rotating drum apparatus (shown here as Fig F7) for measuring length (lunghessa) and duration (durata) of flame (fiamma) produced on explosion. It consists of the following parts: electric motor (elettromotore) with speedometer (tachimetro), photographic apparatus (apparecchio fotografico), electric transmission (trasmissione elettrica) and mortar for firing (mortaiio di sparare), located 6 meters from the apparatus. The mortar consists of a steel block with a hole for explosive charge.

The photographic apparatus consists of camera protected from light (camera a tenuta di luce), which encloses a rotating drum with film (tamburo con pellicola), a screen with a slit (schermo con fessura), and a stand supporting the drum and transmission. At the front part camera, against the slit of the screen is located a lens (lente) which allows the passage of ultraviolet rays of the flame.

The rotation of motor is regulated to cause the peripheral velocity of the drum to be 20 meters per second.

Giorgio (Ref 13) lists rotating drum method and motion picture method and briefly describes the method of Berthmann & Käufer, without giving the information where the method was published, but just the year (1956). The Fig 32 given on p 99 of Ref 13 is shown here as Fig F8. It consists of:

A = rotating drum apparatus with film, B = mortar made of marble, C = spherical vertical mirror and D = spherical horizontal mirror.

US procedures for determining the characteristics of percussion primers include the rapid measurements of flame length, flame duration, flame temperature, etc in a special apparatus. It consists of two major units: the firing chamber (a closed box in which are mounted the sensing elements) and the electronic magnifying glass. It consists of the following parts:

A = rotating drum ensemble with a sensitive film
B = Mortar made of marble
C = Spherical vertical mirror and
D = Spherical horizontal mirror

The first of these mirrors placed near the borehole of mortar produces on the film...
A = Rotating drum apparatus with film
B = Mortar made of marble
C = Spherical vertical mirror
D = Spherical horizontal mirror

FIG F8

of the drum notches permitting one to measure the flame; the 2nd of the mirrors reflects the course of the flame inside the borehole of the mortar even before it leaves the mouth. The results of work with this apparatus showed that the velocity, which is 2000–1000m/sec at the mouth, reaches 2500–2000m/sec outside the mortar.

The drawing of flame shown in Fig 8 may be subdivided into: A = Intense flame of expln; B = Successive luminosity; C = Image of vertical mirror; and D = Image of horizontal mirror control panel. The parameters sensed by the apparatus are displayed on meters or lamps and are expressed as numbers which are arbitrary, but useful for comparing one primer with another. More information about this test is given in Refs 12a & 14


Flameless Cartridge Case of Cocking, mentioned in Vol 3, p C368-R, 4th line from top consisted of a narrow fiber, wool, etc, cylindrical bag (impregnated with Amm chloride soln), in which was placed an explosive cartridge before loading into a borehole. The impregnated bag was supposed to cool the gases of explosion to a point where the fire-damp would not be ignited

Ref: Daniel (1902), 150
Flameless Cartridge Cases (Ger & Amer). Compare with Combustible Cartridge Cases invented in Germany and mentioned in Vol 2, p C78-R.

Compositions of some combustible and semicombustible cases were described by Gen W.K. Gormley in Ord 47, 231—34 (1962)

Some of combs developed at Picatinny Arsenal at the same time of publication of Vol 2 of Encycl (1962) were classified

Flameless Gas-producing Charges. The devices, useful in coal mines or pressure actuated devices, contain NGu, GuN, Nitrodicyandiamine, or Dicyandiamide nitrate with 5−35% of the total charge a hypophosphate such as NaH2PO3, Ca(H2PO3)2, or NH4H2PO3. AN and alkali nitrates are added as needed. When fired with a gasless igniter or a cap, the combs are converted into permanent gases without flame at a temperature below that needed to ignite fire damp
Ref: A.T. Tyre, USP 2470082 (1949) & CA 43, 5190 (1949)

Flameless Securites. These explosives were manufd at Denby, England by Flameless Explosives Co, Ltd at the end of the 19th century. They were used for use in gaseous mines and contained AN, DNB and AmmOx
Ref: Daniel (1902), p 711

Flamelessite. A mixt of nitrates with charcoal and other ingredients used at the end of the 19th century in England
Ref: Daniel (1902), 301

Flame or Light Accompanying Detonation. See under "Detonation (and Explosion); Luminosity (or Luminescence) Produced On" in Vol 4, pp D425-L to D434-L

Flame, Miscellaneous Subjects are discussed in the following:

6) P. Laffitte et al, 10th Symp Combust 1964 (Pub 1965) (Engl) & CA 64, 3275 (1966) (Decompr flame of Hydrogen Azide)
7) H.M. Wight, NASA Accession No N65−22812, Rept No U−29311, 110 pp (1964) (From SciTech Aerospace Rept 3(12), 2073(1963)) & CA 65, 15142 (1966) (Reflection and scattering of sound by flames)
8) J. Adler, Combust Flame 9(3), 273−79 (1965) (Engl) & CA 64, 3275 (1966) (Prediction of laminar flame speeds in stoichio-
metrile mixtures with non-normall diffusion)
12) F.J. Weinberg, Combust Flame 10(3), 267−72 (1966) & CA 65, 19920 (1966) (Direct recording of flame ions on photographic emulsions)

Flame, Muzzle. See Muzzle Flash, under Flash Reducing Compounds
Flame Photometry. An analytical method suitable for qual and quant dem of about 70 elements, flame photometry is based on the classical flame tests for the alkaline and alkaline-earth metals (Na yellow, K purple, Ca brick-red, Sr carmine-red, etc). If a flame can be kept burning uniformly for an extended period of time and material fed into the flame at a constant rate, the intensity of the spectral line or band will be a measure of the concn of the substance. The wave length of the emitted light will permit identification of the excited species.

In addn to being the general term for the field as a whole, flame photometry refers also specifically to systems where the emitted light is separated by filters and the intensities are measured by a photo tube. Flame "spectrophotometry" uses a monochromator to resolve the light. Flame "spectrography" is emission spectrography using flame excitation and photographic recording.


Flameproof (or Fireproof) Compounds are substances used to impregnate various flammable materials to make them fire-resistant or capable of burning without flame. Numerous compds are given in Refs 1 & 2. (See also Fire Resistant Textiles and Fire-Retardant Paints)


Flameproofing Substances. See Flameproof Compounds, Fire Resistant Textiles, and Fire Retardant Paints
Flame Radiations are discussed in the following:


Flame Reactions and Detonations (Flammenreaktionen und Detonationen, in Ger). Title of the Symposium (Diskussionstegung) held under the auspices of the Deutsche Bunsen-Gesellschaft für physikalische Chemie at Tübingen, Germany from 18 to 20 October, 1956

The report (Bericht) of the symposium is published in the Zeitschrift für Elektrochemie, Berichte der Bunsengesellschaft für physikalische Chemie, vol 61, No 5, 1957, Verlag Chemie-GMTH-Weinheim/Bergstr, pages 559–692

The report includes the following papers:

1) W. Jost, Flammenreaktionen und Detonationen (Flame reactions and detonations), introduction, pp 559–62
2) C. Franze & H.G. Wagner, Theorie der Flammenausbreitung (Theory of flame propagation), p 562–4
5) B. Lewis & G. von Elbe, Fundamental Principles of Flammability and Ignition, pp 574–78
6) A. van Tiggelen et al, Eine Beziehung für die Flammengeschwindigkeiten verschiedener Brennstoffgemische (A correlation for velocities of flame propagation of various combustible mixtures), pp 579–83
8) N. Manson, La Théorie Hydrodynamique et le Diamètre Limite de Propagation des Ondes Explosives (Hydrodynamic theory and the maximum limiting diameter of propagation of explosion waves), pp 586–92
9) F.C. Harschbarger, Shock Tube Technique, pp 592–600
11) H. Behrens & F. Rössler, Temperatursmessungen an Russ-strahlen in Flammen (Temperature measurements on jets of carbon black in flames), pp 610–13
12) A. Berthmann, Untersuchungen über den Detonationsvorgang gewerblicher Sprengstoffe hinsichtlich ihrer Zusammenarbeit, Prüfung und ihrer Wirkung in der Praxis (Investigation of the detonation process of industrial expls with regard to their compo, testing and their effect in practice), pp 614–28
13) R. Schall, Methoden und Ergebnisse der Detonationssackbestimmung bei festen Sprengstoffen (Methods and results of the determination of blast pressure of solid explosives), pp 629–35
14) H. Ahrens & E. Eitz, Röntgenblitzaufnahmen zur Untersuchung der Detonationsübertragung bei Wettersprengstoffen (X-ray flash photographs for the investigation of the transmission of detonation of safety mining explosives), pp 635–42
15) J.F. Roth, Versuche mit einem Sospendel zur Aufklärung des Detonationssaklaufes bei Wettersprengstoffen (Investigations with an impact pendulum for
clarifying the detonation path in safety mining explosives), pp 643–51
16) H. Käufer, Untersuchung der Flammenentwicklung bei Sprengstoffdetonationen und der dadurch hervorgerufenen Zündungen eines Methan-Luft-Gemisches bei verschiedenen Schussanordnungen mittels Aufnahmen auf rotierendem Film (Investigation by means of a rotating drum camera of flames evolving from detonations of explosives at various shooting arrangements). These flames cause the ignition of a methane-air mixture), pp 651–62
17) H. Freiwald & H. Ude, Untersuchungen an kugelförmigen Detonationswellen in Gasmischungen (Investigations of spherical detonation waves in gas mixtures), pp 663–72
18) H. Selle, Deflagrations-und Detonationserscheinungen beim Zerfall von Methyl-nitrit (Deflagration and detonation phenomena during the decomposition of methyl nitrite), pp 672–78
19) Th. Just & H.Gg. Wagner, Gleichgewichtseinstellung in Gasdetonationen (The reaching of equilibrium in the detonation of gases), pp 678–85
20) K. Fischer, Ablauf von Kohlenstaubexplosionen (The process of coal dust explosions), pp 685–92 (See also Vol 4, p D348-L, Detonation, Flame Reactions and)

Flame Spectra of Explosives are discussed in the following:

Flame Temperature Determinations are described in the following:

Flame Temperature of Priming Mixture. The flame temperature of a priming mixture can be calculated, by assuming reactions at room temperature and the resulting products then being heated to the adiabatic flame temperature, by the expression:

\[ T_{\text{flame}} = T_{\text{initial}} + \frac{Q_v - \Sigma L_p}{\Sigma C_p} \]

where: \( Q_v \) = heat of reaction at constant volume
\( \Sigma L_p \) = sum of the latent heats of fusion of the products
\( \Sigma C_p \) = heat capacities of the products
For purposes of this calculation, latent heats at constant volume and at constant pressure are assumed equal, heat capacities at constant pressure and at constant volume are assumed equal for solids and liquids. [See also "Calculation of Temperature of Detonation (and Explosion)" and "Experimental Determination of Temperature of Detonation (and Explosion)", under "Detonation (and Explosion) Temperature Developed On" in Vol 4 of Encycl, pp D589-L to D601-R]

Flame Test for Detonators. This test, designed by Dr. Grave, consists of photographing the flash produced by a detonator when exploded. The test is practically valueless because the flame is of nearly the same intensity for different detonators, varying only in size with increase or decrease of the detonator charge.

Flame Tests. See "Flame, Length and Duration of", "Flame Photometry", "Flame Propagation and Velocity" and "Flame Temperature Measurements", in this Vol. Also in Vol 1: "Flame Test", p XII; "Index of Inflammability Test", p XVII and "Sensitivity to Flame, Heat, Sparks, Electrostatic Discharges, etc", p XII & XXIII

French Official Tests 5 & 6 are described in Vol 5 under "ESSAIS d'EXPLOSF", p E138. They are: a) "Combustion en gouttière de 20mm" (Combustion in a 20mm Trough), also known as "Aptitude à l'inflammation" (Capability to Inflame) and b) "Combustion en tas conique" (Combustion in a Conical Pile), also known as "Épreuve de sensibilité à l'inflammation" (Test for Sensitivity to Inflammation)

Flame Theories. The following are some refs on this subject:
6) D.B. Spaulding, 6thSympCombust, Yale Univ 1956, 12-20, 35 refs (PUBL 1957) (Ends and means in flame theory, a review)
(See also "Combustion Theories as Applied to Solid Propellants" in Vol 3 of Encycl, pp C430-L to C435-L)

FLAME THROWERS (Flame Projectors) are devices for throwing a spray of combustible liquids, gels or gas a considerable distance, with the primary object ofbuming enemy personnel and sometimes of igniting easily inflammable material of the enemy.

The origin of gas flame throwers may be traced to the 5th century BC (See under Incendiary Agents), but the liquid flame throwers were invented in about the 7th century for use in conjunction with "Greek Fire". With the invention of gunpowder and guns, flame throwers were forgotten until the Japanese reintroduced them during the Russo-Japanese War of 1904-1905. The Germans worked on their perfection and by 1912 had developed a model which, adopted as standard equipment for the German Army, was used during WWI and served as a prototype for other German, as well as British, French, Italian,
and later, American models of WWI (Refs 1 & 6)

The principle of all flame throwers is practically the same: a flammable liquid or gel contained in a strong metal reservoir is put under heavy pressure by a compressed gas (such as air, CO₂, N₂ or H₂) called propellant, contained in a steel cylinder connected to the reservoir thru a reducing valve, designed to maintain a given pressure in the reservoir. The liquid is forced out of the reservoir thru a pipe fitted with a valve and terminating with a nozzle, of suitable diameter, which directs the stream in the direction desired. The liquid is ignited either at the end of the nozzle by means of a special igniter or, where it is projected onto the earth, by means of incendiary grenades which are thrown into the area reached by the stream.

The ignition of projected liquids is

According to Ray (Ref 1), the following projectors were used during WWI:
1) Stationary type:
   a) German Flammenwerfer contained 45 gals of liquid, which was propelled by compressed nitrogen
   b) French L-1 held 33 gals of liquid, which could be projected by means of compressed air up to 180 feet; the duration of projection was 15 seconds
   c) British Stationary Projector held 80 gals of liquid, which was projected 300 ft by means of compressed "deoxygenated air"
   d) USA. No stationary machine was developed by the US Armed Forces because the usefulness of such machines was questioned

2) The following Portable Type Flame Projectors were developed during WWI:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Weight Charged, lbs</th>
<th>Capacity gals</th>
<th>Propellant</th>
<th>Working Pressure psi</th>
<th>Nozzle Diam inch</th>
<th>Range of Projection ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>German, &quot;Wex&quot;</td>
<td>66</td>
<td>2.5</td>
<td>Nitrogen</td>
<td>288</td>
<td>Interchangeable</td>
<td>80–100</td>
</tr>
<tr>
<td>French P-3</td>
<td>53</td>
<td>3.0</td>
<td>Air</td>
<td>170</td>
<td>0.24</td>
<td>98</td>
</tr>
<tr>
<td>Italian DLF</td>
<td>40</td>
<td>1.5</td>
<td>Air</td>
<td>–</td>
<td>–</td>
<td>83</td>
</tr>
<tr>
<td>British, Lawrence</td>
<td>65–70</td>
<td>3.0–3.5</td>
<td>CO₂</td>
<td>240</td>
<td>0.36–0.48</td>
<td>125</td>
</tr>
<tr>
<td>American, Boyd</td>
<td>70</td>
<td>4.75</td>
<td>H₂</td>
<td>240</td>
<td>0.31</td>
<td>115</td>
</tr>
</tbody>
</table>

affected either by a hydrogen pilot lamp or by a cartridge of a slow-burning, combustible-oxidizing agent mixture attached to the nozzle and ignited by an electric detonator or by friction (Ref 1)

During WWI two kinds of flame projectors were used:
1) Stationary type — large devices, holding up to about 100 gallons of liquid and used for trench defenses
2) Portable type — small devices holding 2–5 gals of liquid, which could be carried on the backs of the operators by means of suitable straps and pads. They threw liquid from 60 to 125 ft and could be emptied of liquid by continuous discharge in less than 20 seconds

For composition of liquids used in these and other projectors, see further under "Flame Throwers—Liquids"

Mechanized or Tank-type Flame Throwers. During WWII a 3rd type of flame thrower was developed, the so-called "tank-mounted" or "mechanized" flame thrower, which at first was intermediate in size between the stationary and portable types but later surpassed the WWI stationary types in size. Although tank-mounted throwers were effective at targets over 200 ft distance, the best results were obtained when operated at extremely close range. The tank, being protected by armor, could approach an enemy's fortification and fill it, thru an embrasure, with flame and smoke, blinding, burning and shocking enemy personnel
The following may be given as examples of tank-type flame throwers:

a) **British Mechanized Thrower** carried by the 41-ton Churchill “Crocodile” tank, threw a geyser of fire over 450 feet and could be reloaded during action because the tank towed its own fuel in an armored trailer.

b) **American Mechanized Thrower**, Model E-9 had a range up to 600 ft and a nozzle diameter of about ½ inch. The fuel was 10% Napalm and was carried in a trailer tank (800–1200 gals capacity) attached by a joint to the M-5A1 tank, in which a gun was mounted. The fuel was ejected by means of compressors at a pressure of 500 psi.

**Portable Flame Throwers of WWII**. There was no progress in the construction of flame throwers between the two wars, consequently, when WWII started, the only available models were those used in WWI. In 1941 work was started in the USA and by 1942 several models of portable throwers were constructed; all of them using one of the newly developed thickened fuels, such as “Gelgas” of the Standard Oil Co (Esso) or “Napalm”, developed at Harvard University. Flame throwers using “Gelgas” were sometimes called “Esso throwers”. The principal ones developed by the US Army were models M-1A1 and M-2, both using Napalm thickened fuel (4.2p of Napalm in 95.8p of ordinary gasoline). In the earlier models ignition of fuel (as it emerged from the ignition head) was done by means of electric sparks, but as this method was reported to be unreliable when used in tropical countries, a new ignition system was developed in which ignition of the fuel was accomplished by flame producing pyrotechnic cartridges.

The later US portable unit carried and fired by one man is described by Fisher (Ref 6, p 51). It weighs 70 lbs and consists of two interconnected fuel tanks (2 gals capacity each) with a pressure tank (containing either nitrogen or air) placed between them. The pressure of the gas in the middle tank is such that it can eject the fuel with a pressure of 2000 psi. The so-called “gun system”, which resembles a Browning pistol in appearance, consists of a trigger, an ignition head, and a hose to convey fuel from the tank to the gun assembly. Before reaching the gun, the fuel must pass thru a valve, which has to be opened by pressure on the “valve lever”. Pressure on the gun trigger activates the ignition device described above. The contents of the tank last only 10 seconds, if ejected in one application. Much better results are obtained by firing the thrower in a series of bursts of 2–3 seconds each. The effective projectory range is up to 125 ft. After firing, the tanks can be refilled for further use.

Towards the end of WWII, in 1945, some very light portable throwers were developed, which were “one-shot” types intended to be discarded after use (Ref 6).

**Rejs**: See below under Flame Throwers—Liquids and Gels.

**Flame Throwers—Liquids and Gels**. One of the original liquids (or semi-liquid, semi-solid) for flame throwers was the so-called “Greek Fire” invented in the 7th century.

The liquids used during WWI and WWII were combinations of heavy and light distillates of petroleum, coal tar or wood tar. The presence of small amounts of light distillates is necessary in order to secure easier ignition, while the presence of heavy distillates is necessary because heavy liquids can be thrown farther and are longer-burning.

The British, French & Italians during WWII used mixtures of heavy and light petroleum distillates with a density of about 0.96 at 15°. The Germans used various mixtures of petroleum distillates, coal tar fractions, and sometimes such liquids as methanol, acetone or even ether. The density of such mixtures was usually about 0.96 at 15°. One of the first American mixtures contained 70% water-gas tar (flash point: 120° and d 1.044) and 30% “benzene heads” (fl p 26° and d 0.756). The resulting mixture had d 1.02. It gave a good trajectory, fierce flame and good throw. Crude benzene was later substituted for the “benzene heads” as being more readily available. In cold weather the amount of benzene could be increased to 40%.
Because flammable liquid materials are not convenient to handle, attempts were made to convert them into a solid state. During WWI solid oils had already been prepbd by treating the petroleum distillates with sodium stearate or other materials, but they were used only in some incendiary bombs, shells, Liven's drums and trench stoves, and not in flame throwers.

At the beginning of WWII, materials used in flame throwers were liquids, which were no better than those used during WWI.

In 1941, exploratory work on incendiary materials was begun under L.F. Fieser at Harvard University (Ref 7). The first material developed was gasoline (80-octane motor-vehicle type), thickened (jelled) by addition of natural rubber. This was a satisfactory product but, due to the shortage of natural rubber, it could not be produced on a large scale. Therefore, a new thickener was developed which consisted of crude aluminum naphthanate modified by addition of Al soaps of coconut oil acids. This thickened gasoline was not very successful at first (See further). Standard Oil Co (Esso) meanwhile developed a very satisfactory thickener, called gelgol or jelled gasoline based on “isobutyl methacrylate polymer” which was adopted by the US Armed Forces as fuel for special flame throwers, called Essoflames. However, the work on naphthenates was continued and success was achieved when purified aluminum naphthenate (by extraction with alcohol or acetone) replaced the impure material. By combining the aluminum salts of naphthenic, oleic and coconut oil acids, a product called Napaln was obtained. This was produced by aqueous coprecipitation with Al₂(SO₄)₃ solution of the mixed sodium soaps of naphthenic, oleic and coconut oil acids in the ratio 1:1:2. The resulting precipitate was filtered, washed with water and dried. It was a granular, non-agglomerating powder which was reasonably resistant to oxidation. This powder could be easily dissolved, by stirring at room temperature, in gasoline or other petroleum hydrocarbons and used, not only in flame throwers, but also in incendiary bombs of different sizes.

For portable American throwers, such as M-1A1 or M-2, 4.2 g of Napalm were dissolved in 95.8 g of ordinary gasoline at a temp above 15.5°(60°F). For “mechanized” (tank) flame throwers, as for instance Model E9, a 10% solution of Napalm was used.

It should be noted that Napalm gels were better suited for flame throwers than any of the existing thickened fuels. Gels based on the isobutylmethacrylate polymer, while very suitable for loading incendiary bombs, when used in flame throwers had a tendency not to issue from the nozzle in a continuous (uninterrupted) stream, as the Napalm gels do, but to pull apart into separate small chunks. This offered so great a surface that drag, owing to air resistance, reduced the range. It can be said that “Esso” gels lack “stringiness” or are “short”.

Another advantage of Napalm gels lies in the fact that they are anomalous (pseudoplastic) in their flow characteristics. This means that these gels do not obey the “Newtonian” laws of flow for ordinary liquids, such as lubricating oils. When these (Newtonian) liquids are caused to flow thru a narrow tube or orifice, under pressure, the flow is directly proportional to the pressure as long as the turbulent flow range is not reached, meaning that if the pressure is increased twice, the flow is also doubled. This is not true for Napalm gels, in which the rate of flow increases much faster than the increase in pressure. For example, with a 6% Napalm gel, an increase of pressure equal to 25% increased the rate of flow thru a 1½ inch pipe nearly a thousand-fold (Ref 7).

During WWII, the British used a thickened fuel called Fras which was prepared by digestion of aluminum stearate with gasoline at 50–55°(120–130°F), but this material was not as good as Napalm and more difficult to prepare (Ref 7).

It should be noted that the use of thickened fuels not only solved the problem of easier handling, but it also increased the throwing range as well and produced a more regular trajectory. In addition, due to the fact that the gel easily adheres to the objects it hits (or even envelopes them) and does not splash as liquids do, a hotter and more concentrated flame is produced.
By using these fuels, it was possible to fire "around a corner", meaning that the stream of jelly can be directed on the fortification from the flank out of range of enemy guns. After striking the sides of the gun port, the jelly spatters inside the fortification, burning the gun crew and suffocating them by using up the oxygen present.

For filling incendiary bombs, a thicker solution was used than for flame throwers. For instance, for M-69, small incendiary bomb, the following composition was used: Napalm thickener 9 to 12, gasoline 91 to 88. Pyrogel or "Goop": Sticky and doughy gray mass, also called "synthetic lava" was prepared by mixing jellied gasoline with "crude magnesium" powder, liquid asphalt & petroleum oils. The crude magnesium was obtained as a residue from production of high grade magnesium by the Hunsigir process. Pyrogel was used in the so-called M-76 "Goop" bomb, also called "Block buster", described under Incendiary Warfare. This mixture combined the properties of jellied gasoline and magnesium as follows: a) it spouts flame like gasoline; b) emits very intense radiant heat of a burning metal; c) burns downward as well as upward and d) continues to burn and flare up for a considerable period of time; e) sticks to objects and penetrates into hard-to-reach corners of structures.


### Table 6-6

<table>
<thead>
<tr>
<th>NaCl (g)</th>
<th>HCl (g)</th>
<th>NaOH (g)</th>
<th>HNO₃ (g)</th>
<th>H₂SO₄ (g)</th>
<th>H₂CO₃ (g)</th>
<th>H₂O (g)</th>
<th>Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
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<td>0.2</td>
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<td>0.2</td>
<td>16.0</td>
</tr>
</tbody>
</table>

## Composition of Pumice Mixtures—Cell Type

<table>
<thead>
<tr>
<th>Composition</th>
<th>Pumice Mixtures—Cell Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>0.2</td>
</tr>
<tr>
<td>HCl</td>
<td>0.2</td>
</tr>
<tr>
<td>NaOH</td>
<td>0.2</td>
</tr>
<tr>
<td>HNO₃</td>
<td>0.2</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>0.2</td>
</tr>
<tr>
<td>H₂CO₃</td>
<td>0.2</td>
</tr>
</tbody>
</table>

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F59

Re: "E. coli & L. Frankelita, "History of R & D at the CSIS in DFW," 1 July 1941, between 1941-1943, Incal.

In December 1943, Vol 18, Part IV (1943), p 662.
Flame Thrower-M132A (Amer). A self-propelled device (designed and manufactured at Edgewood Arsenal, Md) which is capable of throwing a steady stream of flame more than 150 yards. Operated by a two-man crew, the thrower can fire continuously for 30 seconds or may be fired in bursts. Ref: Anon, Ordnance, July-Aug 1968, p 30-L.

Flamethrower, Portable for Lighting Fuses. See Vol 4 of Encyl, p D762-L.

Flaming Bayonet, invented during WWI, was a flame throwing type of attachment for the muzzle of a military rifle. It was for use in bayonet fighting and consisted of either a small (less than 1 lb) charge of flammable liquid or of a cartridge containing a flash composition. When the bayonet hit a target, a spurt of flame 10–30 ft in length was produced. The cartridge type was considered superior to the liquid type. Ref: Anon, "History of Trench Warfare Material," Army Ordnance Handbook No 154, Govt Printing Off, Wash, DC (1920), pp 217–18.

Flaming Thermit. An incendiary mixture developed by the British during WWI and used in their small unit (cluster) bombs. It was a mixture of commercial thermit and barium nitrate.

Flammability. Its definition and brief description are given in Vol 5, pp D211-L to D213-L under "Detonability and Flammability of Explosives, Propellants and Pyrotechnic Compositions."

Flammability of Black Powder Igniter Bag by firing in a nanometric bomb is described by A. Doilliet & P. Minaud in MP 36, 277–84 (1954) & CA 50, 3764 (1956). The same technique was used as described by the same investigators in MP 34, 221–36 (1952) & CA 48, 4838 (1954). (See also under Flammability of Propellants.)


Flammability and Explosibility of Dusts. Various tests are described under "Burning (Combustion) and Deflagration of Gases, Vapors and Dusts" in Vol 4 of Encyl, pp D154-L to D163-L. Also "Dust Explosibility" and "Dust Explosions" in Vol 5, pp D1578-L to D1579-R.

Flammability and Explosibility of Gases and Vapors. See above item.

Flammability of Explosives, Propellants and Pyrotechnic Compositions. See under Detonability and Flammability of Explosives, Propellants and Pyrotechnic Compositions in Vol 4 of Encyl, pp D211-L to D213-L.


Flammability Limits of Methanol-Air Mixtures: The Effect of Water Vapor on, is discussed by K. Dvořák & A. Reiser in ChemLisy 49, 467-72 (1955) & CA 49, 9927 (1955) (A static app suitable for liquid fuels is described. Results for water-methane-air mixtures are given. A simple correlation method on the basis of heat balances is attempted).

Flammability of Nitrocellulose. Highly dangerous in the dry state when exposed to heat, flame or powerful oxidizers. When wet with 35% denatured alc, it is about as hazardous.
as ethyl alcohol or gasoline. Dry NC burns rapidly with intense heat and ignites very easily
Ref: Sax, 3rd ed (1968), p 965-R


Flammability of Powders. A German apparatus for measuring the "Entzündungsfähigkeit des Pulvers" was described by N.L. Hansen in SS 2, 165-67 (1913)

Flammability of Propellant. The flammability of French propellants "poudre B" and "poudre Néco" were deduced in high pressure bombs, by measuring the time from firing to rise of pressure due to ignition by Black Powder

Flammability Ranges and Spontaneous Ignition of Some Fuels in Air were deduced by J.H. Burgoin & R.F. Neale in Fuel 32, 5-27 (1953) & CA 47, 2577-79 (1953)

Flammability, Surface, of Materials: Measuring it by Using a Radiant Energy Source was described by A.F. Robertson et al in ASTM 1956, Preprint 67, 17pp & CA 50, 13443 (1956)

Flammability Test for Thin Flexible Materials is described giving details of construction of apparatus in the British Standards Institute, Brit Standard 476 (1955), Pt 2, 11pp & CA 50, 7462 (1956)

Flammable Inhibitors Can Prevent Explosions in Chemical Plants. In a system where a combustible and oxygen (from air or added pure) are to be reacted and the operating conditions require an explosion and temps near the ignition temp, the possibility of explosion can be eliminated by adding a diluent to the system. Diluting with combustible or oxygen may upset the stoichiometry of the system, and use of a sufficient quantity of inert gas may make the process uneconomical. A relatively small amount of a hydrocarbon (CH₄, etc) has been found to be as effective as a much larger amount of an inert gas in diluting the mixture. It is essential to stay below the lower explosion limits of the hydrocarbon and oxygen, obviously
Ref: E. Jones, Chem. Engr 59, 185-8 (1952)

Flammable Mass. A mass useful for making sparklers, etc is made by adding to a mix of Al powder, KNO₃ and/or KClO₃ and rice starch or dry powdered CaCO₃. Perfume or incense may be added to the mass which burns down with fogging and formation of snow-like flakes

Flammable Materials, Storage and Handling. Since it is not economically feasible to store each item of inventory under ideally safe conditions, a compromise must be made between perfect safety and industrial economy. Standard works such as those listed in the Refs should be consulted for general guidance and for information on specific points
Refs: 1) Factory Mutual System, "Handbook of Industrial Loss Prevention", 2nd Ed, McGraw-Hill, NY (1967) (Consult the book's index under storage; there is no chapter devoted to storage as such) 2) Sax (1968), pp 208-26 discusses storage and handling in general, and pp 365-1251 is an alphabetical list of specific substances 3) National Fire Codes. An annual set of 10 vols published by National Fire Protection Association (NFPA): Vol 1, "Flammable Liquids"; Vol 2, "Dusts"; and Vol 3, "Combustible Solids, Dusts, and Explosives" are most pertinent to this topic
**Flammenbombe.** A German incendiary bomb of WWII contg an oil mixture and a HE bursting charge. The following types are described in Ref 1 and listed in Ref 2:

a) Flam C 250A (B or C) — contd 50kg of oil incendiary mixt and TNT bursting charge

b) Flam KC250 — same filling as above
c) Flam C500 — contd the incendiary oil consisting of 70% petroleum with 30% TNT dissolved and TNT bursting charge

*Refs:* 1] Anon, TM 9-1985-2 (1953), pp 52-4

**Flammenauslöschenzusatz.** Ger for "Flame Extinguishing Addition", described here under "Flash Reducing Compounds"

**Flammivores.** A series of Belgian permissible expls manufd from 1887 on by Société Anonyme des Poudres et Dynamites d’Atendovck. Several formulations are given in the Table F7


(See also Vol 2 of Encycl, p B29-R)

**Flammocite.** An explosive which was not allowed as a permissible in France but was used in Belgium under the name of Flammivore 3-bis: NG 6, AN 44, AmmSO₄ 5, Sn 14, NaCl 16, TNT 10, cellulose 5

*Ref:* E. Audubert, Chim & Ind (Paris) 10, 929 (1923) & CA 18, 471 (1924)

**Flanschgeschoss (Ger) (Flange Projectile),** also called "Squeeze-bore", or "Littlejohn" was a subcaliber projectile provided with a flange and three hollow studs as shown on Figure and described in the TM 9-1985-3, p 356

It was fired from a cylindrical rifled barrel to which a smooth-bored, tapered muzzle extension was attached

The principal advantage of the "flange" projectile in comparison to the other sub-caliber projectiles was that it had no parts to be discarded, because the hollow stud and the flange were easily depressed when the projectile passed through the rifled section of the gun to the smaller caliber smooth bore extension

(Compare with Arrowhead Projectile, Arrow or Needle Projectile, Disintegrating Band Projectile, Röchling Projectile, Sabot Projectile and Tapered Bore Projectile)

*Ref:* PATR 2510 (1958), p Ger 49

### Table F7

(Flammivores)

<table>
<thead>
<tr>
<th></th>
<th>Ref 1</th>
<th>Ref 2</th>
<th>Ref 3 No 1</th>
<th>5-bis</th>
<th>V</th>
<th>IV</th>
<th>couche</th>
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<tr>
<td>AN</td>
<td>85</td>
<td>70</td>
<td>82</td>
<td>59</td>
<td>60</td>
<td>98.5</td>
<td>47</td>
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<tr>
<td>SN (Na nitrate)</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>NG</td>
<td>-</td>
<td>6</td>
<td>4</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>BaSO₄</td>
<td>-</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AmmSO₄</td>
<td>5</td>
<td>9</td>
<td>-</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CC (CollodCott)</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DNT</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>NaCl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Cellulose</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.85</td>
<td>4.45</td>
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<td>Lampblack</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Carbohydrates</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Dextrin-starch</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>-</td>
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</tr>
</tbody>
</table>
FLARE (Blaze or Glare).

Flare is a pyrotechnic device producing bright, dazzling, broad light intended for signalling, attracting attention, or illuminating the terrain. They may also be used for identification, ignition, location of position or warning.

Essentially, a flare consists of a container (metal, cardboard, plastic, paper etc) filled with a pyrotechnic mixture consisting of compressed illuminating composition and an igniting composition (first fire), such as Black Powder or a mixture of Black Powder and the illuminating composition. The first fire composition is usually ignited either electrically by a squib, or mechanically by a spring release pin hitting a primer when a pull wire is withdrawn.

Among devices used during WWI, the following may be mentioned:

1) **German White Flare** — contained as illuminating charge, compressed Ba(NO₃)₂ 61.5, Al powder 20, sulfur 18.5 (Ref 1, v 1, p 191)

2) **Ground Flares** — These flares, when ignited in a trench or shell hole, were distinctly visible from airplanes even in daytime, but were completely hidden from the enemy. The following compositions were used:
   a) Ba(NO₃)₂ 82.5, tar 14.5, nitrates of Ca and Mg 3.0%
   b) Ba(NO₃)₂ 66.4, KNO₃ 9.5, powdered Al 7.5, resin (wood tar, pitch) with some oil & wood fiber 15.8 and volatile matter 0.8% (Ref 1, v 1, p 194)

3) **Aircraft Flare** — was invented by the French and consisted of a metal container (cylindrical, bomb-like), loaded with compressed white light illuminating composition [Ba(NO₃)₂ 76.00, Al (powdered) 9.75, Al (flaked) 8.25, sulfur (flour) 4.00 and castor oil or vaselin 2.00%] and a first fire composition [Ba(NO₃)₂ 44.5, KNO₃ 33.3, sulfur (flour) 11.1 and orange shellac (powder) 11.1%]. The tail end of the bomb provided with four fins (to assist the flight) and a large silk parachute. The flare was usually released at a height of about 4000 ft. At about 2500 ft, the parachute was released by means of an expelling charge of Black Powder, following this, the first fire and then the illuminating compositions were ignited. These flares burned with an intensity of not less than 35000 candlepower (Ref 1, v 2, pp 99, 111 & 118 and Ref 3, p 72).

During WWII, much greater varieties of flares were used than in WWI. Most of the flares developed were for airplane use (See Fig 2-75 in Vol 4, p D957).

Following are some flares used by the US Armed Forces:

1) **Aircraft Wing-Tip Flares** — intended for signalling and assisting planes in landing. They were attached to the extremities of the
wings and ignited by "flash igniters", electrically controlled by the pilot. They consisted of a paper tube, 4 inches long and 1¼ inches in diameter, filled with an illuminating composition and closed at both ends with wooden plugs. They usually produced white, red or green lights (Ref 2, p 74)

2) Flares Released from Aircraft, such as:
   a) Flare, AN-M26 designed to provide illumination for night bombardments. It was in the shape of a bomb, and was provided with fins and a parachute. The total weight was 52.5 lb. The illuminating composition (which was in compressed form) burned for 3-35 minutes with a yellowish light and a minimum candlepower of 800000. This flare was released at high altitudes at plane speed up to 300 mph (Ref 2, p 315)

   b) Flare, M24 - designed for bombardment, as well as for illumination, weighed 47 lbs and was released from altitudes of from 2500 to 3000 ft at speeds not over 200 mph. In order that the bombadier and plane could be shielded from the glare of the flare, an umbrella-like shade was provided (Ref 2, p 316)

3) Colored Low-Target Flare, M50 was developed in 1944 when mass concentration of planes for night aerial attacks had grown so heavy that some method of identifying group leaders in the air was required. This flare was towed by a cable behind the plane of each leader, with each leader having a different colored flare. Burning time was five minutes and candlepower 20000 to 225000 (Ref 2, p 316)

4) Reconnaissance and Landing Flares were used for illuminating an area at night either to obtain information or for an emergency landing. To this class belonged:
   a) Aircraft Parachute Flare, M9A1. It was a cylinder 2 inches in diameter and 15 inches long, weighing 2.1 lbs and burning for 1 min with a white light of 60000 candlepower. It was discharged from a special pistol (Ref 2, p 317)

   b) Aircraft Parachute Flare, M9A1 - intended for emergency night landings, weighed 18 lbs, burned for 3 min with a yellowish light of 350000 candlepower (Ref 2, p 318)

5) Airport Flares - designed to provide illumination for aircraft landings at emergency fields or recently captured fields before regular electrical illumination could be installed.

To these belonged:
   a) Airport Flare, M13 - in the shape of a cylinder, 23 inches long and 1.75 inches in diameter. The composition burned for 3 min at 40000 candlepower

   b) Airport Flare, M76 - larger than the previous one and burned for 5-7 mins at 700000 candlepower

6) Trip Flares were constructed like an antipersonnel mine of the "Bouncing Betty" type, the fragmentation projectile being replaced by a flare which was projected upwards when anyone came in contact with the device. These flares were intended to give warning of the presence of enemy in their vicinity. The following may be cited as examples:
   a) Trip Flare, M48 - projected a flare, provided with a parachute, to a height of 300 to 500 ft. Time of burning was 20 secs and candlepower 110000 (Ref 2, p 303)

   b) Trip Flare, M49 - designed for the same purpose as the previous one but was not of the bouncing type. It was attached to a pole or tree and functioned by the trip wire being pulled or cut. Time of burning was 60 secs and candlepower 400000 (Ref 2, p 304)

7) Fusee-Type Flares were ground flares, designed for troop-recognition purposes or to indicate to cooperating air elements a line of position or direction. A typical flare consisted of a paper cylinder, 7¼ inches long and 1½ inches in diameter, containing pyrotechnic composition and placed on a wooden block base to which a spike was attached so that the flare could be stuck into the ground. These flares burned for 2 mins; candlepower being 20000 to 35000 (Ref 2, p 306)

8) Hand Illuminating Flares could be thrown by hand, like grenades, or launched from a rifle by means of a propellant charge. These flares were the same in design as M49 (See above)

9) Tree-Suspended Flare was usually suspended above the ground near the front lines and could be ignited either electrically or by pull wires. In its design, it was a modification of the M26 Flare (Ref 2, p 306)

   The following may be mentioned as typical flare compositions used during WWII:
   a) White Flare: Ba(NO₃)₂, 66, Al Type B (See Spec JAN-A-289) 26, sulfur 5 and castor oil 2%. A charge of 500 g, compressed at 6000 psi, burned for 65 seconds, developing 600000 candlepower
## TABLE 1

CHARACTERISTICS OF VARIOUS ILLUMINATING FLARES

<table>
<thead>
<tr>
<th>Item</th>
<th>Method of actuation</th>
<th>Time laps from actuation to full function, sec</th>
<th>Burning time, sec</th>
<th>Candle power, 10^4</th>
<th>Fall, fps</th>
<th>Max L, in.</th>
<th>Max dia, in.</th>
<th>Weight, lb</th>
<th>Max speed of airplane at time of release, mph</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLARE, AIRCRAFT:</strong>&lt;br&gt;Guides, T6E1 (white)&lt;br&gt;T7E1 (red)&lt;br&gt;T8E1 (green)</td>
<td>Electricity</td>
<td>6 to 7</td>
<td>45 to 60</td>
<td>650</td>
<td>700</td>
<td>90</td>
<td>5.4</td>
<td>5.46</td>
<td>..........................</td>
</tr>
<tr>
<td><strong>FLARE, AIRCRAFT:</strong>&lt;br&gt; parachute&lt;br&gt;M8A1 (w/o suspension bands) (emergency night landing)&lt;br&gt;M8A1 (training) (w/o suspension bands)</td>
<td>Release from airplane</td>
<td>3.0 to 5.0</td>
<td>165 to 195</td>
<td>350</td>
<td>8.0</td>
<td>25.42</td>
<td>4.25</td>
<td>17.6</td>
<td>200</td>
</tr>
<tr>
<td><strong>M9A1</strong></td>
<td>Fired from FISTOL, pyrotechnic, AN-M8</td>
<td>2.5</td>
<td>60 to 70</td>
<td>60</td>
<td>7.0</td>
<td>15.05</td>
<td>2.0</td>
<td>2.11</td>
<td>200</td>
</tr>
<tr>
<td><strong>M28A1 (AN-M26) or M26</strong>&lt;br&gt;M26A1 (AN-M26) or M26 (w/blue band)</td>
<td>Released from airplane</td>
<td>5 to 92</td>
<td>105±15</td>
<td>530</td>
<td>675</td>
<td>11.6</td>
<td>50.0 (fused)</td>
<td>8.0</td>
<td>52.5</td>
</tr>
<tr>
<td><strong>M138 (T10E4)</strong>&lt;br&gt;M139 (T10EE)</td>
<td>Released from airplane</td>
<td>5 to 92</td>
<td>180</td>
<td>1,000</td>
<td>3,000</td>
<td>10</td>
<td>45.6</td>
<td>6.25</td>
<td>62</td>
</tr>
<tr>
<td><strong>Mk 5 and Mods</strong></td>
<td>variable</td>
<td>180</td>
<td>600</td>
<td>27.0</td>
<td>4.75</td>
<td>18.0</td>
<td>..........................</td>
<td></td>
<td></td>
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<tr>
<td><strong>Mk 6 Mod 5</strong>&lt;br&gt;Mk 6 Mod 6&lt;br&gt;AN-Mk 8 Mod 1&lt;br&gt;AN-Mk 8 Mod 2</td>
<td>variable</td>
<td>90</td>
<td>180</td>
<td>1,000</td>
<td>800</td>
<td>8.0</td>
<td>25.12</td>
<td>4.75</td>
<td>18</td>
</tr>
<tr>
<td><strong>3 minute, electrically operated</strong>&lt;br&gt;<strong>3 minute, Wiley SA 8</strong></td>
<td>1½</td>
<td>180</td>
<td>200</td>
<td>9.1</td>
<td>28</td>
<td>4.5</td>
<td>22</td>
<td>..........................</td>
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<tr>
<td><strong>FLARE, AIRCRAFT:</strong>&lt;br&gt;tow-target, M50</td>
<td>0</td>
<td>360</td>
<td>65</td>
<td>22.8</td>
<td>2.62</td>
<td>7.13</td>
<td>120</td>
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<tr>
<td><strong>FLARE, AIRCRAFT:</strong> towed&lt;br&gt;Red, M77 (T18)&lt;br&gt;Amber, M78 (T19)&lt;br&gt;Green, M79 (T20)</td>
<td>Tow cable attached to airplane</td>
<td>0</td>
<td>360±30</td>
<td>225</td>
<td>70</td>
<td>90</td>
<td>23.34</td>
<td>4.55</td>
<td>21</td>
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<tr>
<td><strong>FLARE, SURFACE:</strong>&lt;br&gt;Airport, M74</td>
<td>Hand or electric squib</td>
<td>0</td>
<td>300 to 420</td>
<td>600 to 850</td>
<td>31.33</td>
<td>4.26</td>
<td>27.6</td>
<td>..........................</td>
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</tr>
<tr>
<td>Parachute, trip, M48</td>
<td>Pressure or trip wire</td>
<td>3</td>
<td>20</td>
<td>110</td>
<td>3</td>
<td>9.75</td>
<td>5.5</td>
<td>5.0</td>
<td>..........................</td>
</tr>
<tr>
<td>Trip, M49</td>
<td>Trip wire</td>
<td>0</td>
<td>55</td>
<td>40</td>
<td>6.75</td>
<td>3.0</td>
<td>1.5</td>
<td>..........................</td>
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</table>
### TABLE 2

**HAND-MANIPULATED SIGNALING DEVICES SUMMARY**

<table>
<thead>
<tr>
<th>Item</th>
<th>Launched From</th>
<th>Display</th>
<th>Burn Time (Sec.)</th>
<th>Min. Alt. (Fl.) *</th>
<th>Max. Lght. (In.)</th>
<th>Max. Diam. (In.)</th>
<th>Max. Approx. Weight (Oz.)</th>
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</thead>
<tbody>
<tr>
<td>Signal, Illum., Marine, Mk 2 (Very Signal Cartridge)</td>
<td>Pyrotechnic Pistol Mk E</td>
<td>Free-falling Red, Green, or White Star</td>
<td>6</td>
<td>200</td>
<td>2.43</td>
<td>0.88</td>
<td>1.1</td>
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<tr>
<td>Signal, Smoke, Marine, Mk 2 Mods (Pistol Rocket Signal)</td>
<td>Pyrotechnic Pistol Mk 1 or AN-M8</td>
<td>Parachute-Suspended Colored Smoke</td>
<td>20-30</td>
<td>500</td>
<td>14.00</td>
<td>1.65</td>
<td>16.0</td>
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<tr>
<td>Signal, Illum., Aircraft, AN-N37A2 thru AN-M42A2</td>
<td>Pyrotechnic Pistol AN-M8</td>
<td>Two Free-falling Colored Stars (Same or Different Colors)</td>
<td>7</td>
<td>250</td>
<td>8.55</td>
<td>1.57</td>
<td>6.0</td>
</tr>
<tr>
<td>Signal, Illum., Aircraft, AN-M43A2 thru AN-M45A2</td>
<td>Pyrotechnic Pistol AN-M8</td>
<td>Free-falling Single Red, Green, or Yellow Star</td>
<td>7</td>
<td>250</td>
<td>8.55</td>
<td>1.57</td>
<td>8.0</td>
</tr>
<tr>
<td>Signal, Illum., Aircraft, AN-33A2 thru AN-M8A2</td>
<td>Pyrotechnic Pistol AN-M8</td>
<td>Free-falling Tracer and Two Colored Stars (Same or Different Colors)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td>Signal, Illum., Marine, Mk 1 Mods (Pistol Rocket Signal)</td>
<td>Pyrotechnic Pistol Mk 1 or AN-M8</td>
<td>Mod 0: Free-falling Red, Gr. or Y Star Mod 1: Para-Susp. Red Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Grenade, Rifle, Smoke, M22A2</td>
<td>Rifle Launcher</td>
<td>Grenade Smoke Cloud on Impact</td>
<td>8</td>
<td>600</td>
<td>10.14</td>
<td>1.33</td>
<td>16</td>
</tr>
<tr>
<td>Grenade, Rifle, Smoke, Streamer, M23 and M25A1</td>
<td>Rifle Launcher</td>
<td>Streams of Colored Smoke During Flight</td>
<td>12</td>
<td>600</td>
<td>10.5</td>
<td>1.9</td>
<td>18</td>
</tr>
<tr>
<td>Signal, Smoke, Ground, M62, M64, and M65</td>
<td>Rifle Launcher</td>
<td>Six Smoke Streamers: M62-Red, M64-Yellow, M65-Green</td>
<td>20</td>
<td>600</td>
<td>10.4</td>
<td>1.88</td>
<td>15</td>
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<tr>
<td>Navy Light, Mk 1 Mods (Fuse, Warning Railrood)</td>
<td>Held in Hand While Functioning</td>
<td>Mod 0 - Red Light Mod 1 - Blue Light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal, Smoke and Illum., Marine, Mk 13 (Signal, Distress, Day &amp; Night)</td>
<td>Held in hand while functioning</td>
<td>Day-Orange Smoke Night-Red Flame</td>
<td>20</td>
<td></td>
<td>9.5</td>
<td>1.45</td>
<td>7</td>
</tr>
</tbody>
</table>

* Above launch point

(Continued)
Ideal Military Flares. Today flares are used primarily for illuminating and signaling. Characteristics of various illuminating flares are shown in Table 1 (Ref K) and those of signaling flares are shown in Table 2 (Ref M). Illuminating flares produce essentially white light, having an intensity in foot-candles adequate to produce a brightness level from 0.1 to 1.0 foot-lambert and burn at peak intensity for a minimum of 30 secs. Signal flares are smaller and faster burning than illuminating flares. They consist of one or more colored stars with or without colored tracers. They are usually supported by a parachute and are fired from a flare pistol or projector. Aircraft parachute flare, MK5, a typical illuminating flare is shown in Fig 1, while a typical tow target illuminating flare is shown in Fig 2. Two typical signaling flares are shown in Figs 3 & 4.


### Table 2 (Continuation)

<table>
<thead>
<tr>
<th>Item</th>
<th>Launched From</th>
<th>Display</th>
<th>Burn Time (Sec.)</th>
<th>Min. Alt. (Fl.)</th>
<th>Max. Lght. (In.)</th>
<th>Max. Diam. (In.)</th>
<th>Approx. Weight (Oz.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal, Smoke and Illum., Marine, Mk 36</td>
<td>Held in Hand while functioning</td>
<td>Day-Green Smoke Night-Green Flame</td>
<td>5-18</td>
<td>1.63</td>
<td>6.4</td>
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<td></td>
</tr>
<tr>
<td>Signal, Illum., Marine, AN-M75</td>
<td>Hand, Outer case is projector</td>
<td>Two Free-falling Red Stars</td>
<td>5</td>
<td>175</td>
<td>5.0</td>
<td>1.25</td>
<td>5.5</td>
</tr>
<tr>
<td>Signal, Hand Fired, Mk 80 (Contained in Signal, Kit, Illum., Mk 79, Mod O)</td>
<td>Signal Projector, Mk 3I Mod 0</td>
<td>Single Free-falling Red Star</td>
<td>4.5</td>
<td>220</td>
<td>2.25</td>
<td>0.52</td>
<td>12</td>
</tr>
<tr>
<td>Signal, Illum., Aircraft, Mk 6 Mod O (A/C Emerg. Ident. Signal)</td>
<td>Hand-thrown From Aircraft, Grenade Type</td>
<td>Para-Suspended Red, Green, or White Star</td>
<td>25</td>
<td>—</td>
<td>5.95</td>
<td>2.6</td>
<td>13</td>
</tr>
<tr>
<td>Signal, Smoke, Aircraft, Mk 7 Mod O (A/C Emerg. Ident. Signal)</td>
<td>Hand-thrown From Aircraft, Grenade Type</td>
<td>Para-Suspended Red, Green, Yellow, or Black Smoke</td>
<td>25</td>
<td>—</td>
<td>9.57</td>
<td>2.5</td>
<td>28</td>
</tr>
<tr>
<td>Fuse, Warning, Railroad, M72</td>
<td>Ground Hand-Emplaced</td>
<td>Red Flame</td>
<td>20 Minutes</td>
<td>—</td>
<td>15.88</td>
<td>0.9</td>
<td>10</td>
</tr>
<tr>
<td>Grenade, Hand, Smoke, HC, AN-M6</td>
<td>Hand-Thrown</td>
<td>White Smoke Cloud</td>
<td>105</td>
<td>—</td>
<td>4.5</td>
<td>2.5</td>
<td>23</td>
</tr>
<tr>
<td>Grenade, Hand, Smoke, M18</td>
<td>Hand-Thrown</td>
<td>Red, Green, Yellow, Violet Smoke</td>
<td>50</td>
<td>—</td>
<td>4.5</td>
<td>2.5</td>
<td>23</td>
</tr>
<tr>
<td>Cartridge, Signal, Mk 150</td>
<td>38-Caliber Revolver</td>
<td>Red Streak</td>
<td>5.5 - 7.5</td>
<td>800</td>
<td>1.53</td>
<td>0.378</td>
<td>0.39</td>
</tr>
</tbody>
</table>

* Above launch point

b) Yellow Tinted Flare: \( \text{Ba(NO}_2\)\text{)} 34, Magnesium Type III (Spec JAN-M-382A) pre-coated with 6% linseed oil 35; Al Type B (See Spec JAN-A-289) B, Na oxalate 20, linseed oil 1 and castor oil 1%. Chge of 6300g, compressed at 3600psi burned for 280 secs, developing 556000 candlepower.

FIG 1  Aircraft Parachute Flare, Mk 5
FIG 2 Typical Aircraft Tow Target Flare

FIG 3 Signal Flare, M11

FIG 4 Signal Flare, M53A2–M58A2
Flare, Aircraft. See under FLARE

Flare, Airport. See under FLARE

Flareback or Backfire. See under Backflash in Vol 2 of Encycl, pp B2-R to B3-L.

Flare, Float and Flare, Surface. A float flare is a pyrotechnic signal launched from an aircraft to mark a location at sea. It floats on the surface and emits smoke and flare for up to one hour. A surface flare is a pyrotechnic item for use in surface position, ground or water, designed to produce a single source of intense light for purposes such as illumination of airport runway and warning of infiltrating enemy troops.

Ref: Glossary of Ordn (1959), 119-L & R

Flare-Fusee. See under FLARE

Flare, German. (Leuchtkugel oder Fackel). These flares usually consisted of a cylindrical container housing an illuminating element. Upon being ignited by a pull friction igniter or a time fuze, the flare burned vigorously producing intense light and heat. The illuminating element consisted either of a single or a multiple candle unit which varied in intensity of illumination and color. Flares were made with or without parachutes.

A brief description of the following flares was given in Refs 1 & 2, and they are illustrated in Fig F9.
1) LC 10 (Leuchtylindrisch 10) consisted of an Al cylinder, a single candle in a cardboard liner, an "89" clockwork fuze and a parachute located in the tail end. The flare was dropped from a plane and at a predetermined time the fuze fired and ejected the candle and its parachute from the body. Simultaneously the candle was ignited.
2) FB 50, Single Candle Parachute Flare Flare is described on p 66 of Ref 1.
3) LC 50F Ausf C Parachute Flare consisted of a cylindrical Al body with dome-shaped nose attached by means of brass screws.

On releasing the flare, the pyrotechnic delay (inside the fuze) was ignited. This fired the quickmatch, which in turn burned thru the flash tube and ignited the Black Powder charge in the tail. The pressure of the gases developed by the deflagrating BkPdr caused all four flare candles and the parachute to be expelled thru the nose, after shearing the holding screws. Simultaneously, the candles were ignited thru perforations in the ejector plate. The compass of the candle was Barium nitrate 75.8, Al 16.5 and S 7.7%. The burning time was slightly over 5 min and the candle power 216000.

4) LC 50F Ausf E, Single Candle Parachute Flare is described on pp 68-9 of Ref 1.
5) LC 50F Ausf G, Single Candle Parachute Flare is described on pp 69-70 of Ref 1.
6) Mark C 50 F/A Parachute Flare consisted of a cylindrical Al housing contg a parachute, fuze, quickmatch, single candle unit, flash tube, priming compn and ejection disk. When the flare was released, the aerial burst fuze started to function. The flash ignited the quickmatch and the flame was transmitted thru the flash tube to the tail end to ignite the ejection disk of BkPdr. The pressure of the gases developed by the burning BkPdr expelled the parachute and the candle thru the nose. Simultaneously the primer compn and the candle were ignited.

7) Mark 50 Kaskade Target Indicating Flare consisted of a cylindrical sheet metal container 7.7 inches diam and 41.0 inches long contg 62 flares (in three layers separated by perforated cardboard partitions), an expelling charge of BkPdr, smokeless propht ignition disks and an igniter (fuze) assembly. A heavy concrete nose was provided to make the missile fall with the nose downwards, when released from a plane. As the missile fell, the expelling charge was ignited, thus ejecting the flares (candles). At the same time the propht ignition disks ignited each candle. (Composition of candles is given under Pyrotechnics [See also BIOS Rept 1233 (1946), p 1].

8) Single Candle Parachute Flare with Pull Igniter was similar in construction to the Mark C50F/A flare. The principal difference
was that the candle was reversed and ignited by pull (friction) igniters instead of by a BkPdr charge. After the flare was released from the aircraft, the fuze (thru the flash tube) ignited the ejection charge of BkPdr and the pressure of the gases ejected the parachute and the candle thru the nose. At the same time the parachute pulled the cords of the igniters, which were provided with delay elements of 3½ secs. The candle was then ignited and burned for 5 minutes
9) Single Candle Unit Parachute Flare (White) consisted of a cylindrical Al body which was attached to a parachute by means of a cable. Eight shroud lines terminated in a loop which was in turn attached to the pull cord of the igniter. On releasing the flare, the parachute exerted a pull on the igniter "3!" firing cord thus releasing the striker spring. Then the striker hit the percussion cap igniting the BkPdr primer and the candle
10) Single Candle Parachute Flares: 1 (White) and II (Red) are described on pp 75-7 of Ref 1
11) Mark 5 Flares, Types I and 2 consisted of a cylindrical buoyancy chamber which contd two candles. To these were attached a fuze, a static cord and a pull igniter. The static cord functioned either the arming device of the fuze or the pull igniter. When the device was released (from a container) over the water it went under the surface and then came up. It floated with the head of the flare just clear of the water. When the 1st candle was about ¾ burned out, a piece of safety fuse running to the 2nd candle was ignited and, after a short delay, the 2nd candle started to burn. Each candle burned for about 2½ min
12) Smoke Flares: Orange 160 and Orange 80, used as wind drift indicators, are described on pp 79-80 of Ref 1
13) Smoke Signal Flare, used as navigation aids by pilots, is described on p 80 of Ref 1
14) Smoke Signal Flare, ARDR, used for the same purpose as above, is described on p 86 of Ref 1
15) Distress Signal Torch consisted of a narrow sheet Al cylinder contg three pressed charges of flare compo which burned respectively red, white and red. The compo were ignited by a pull igniter
16) Ground Flare, Bodenleuchte (P) Fi56 217

was briefly described in BIOS Final Report 1233(1945), p 2 and the compo of the flare was given under Pyrotechnics
In addn to flares dropped from planes, there were some flares fired from guns, eg the Flare Projectile for the 203mm Railway Gun (20.3cm Leuchtrgranate) described in TM 9-1985-3(1953), pp 519-20. The shell was conventional in design except that it had an additional bourelet machined near the middle of the shell body. The weight of the shell was 226½ lbs, that of the flare candle unit and parachute assembly 47 lbs, and of the expelling charge (BkPdr) ½ lb. The flare and parachute were expelled thru the base of the shell

Flare, Ground. See under FLARE

Flare, Guide. An electrically ignited aircraft flare for attachment to an aerial bomb, which produces a very bright light, either white or colored, to mark the position of the bomb and permits its guidance to the target
Ref: Glossary of Ordn (1959), 119-L

Flare, Guided Missile. A pyrotechnic item designed to produce a single source of intense light for the purpose of visually tracking a guided missile during its flight to a target (Excludes "Guided Missile Tracer" which provides a signal to permit tracking of missile)

Flare, Hand Illuminating. See under FLARE

Flare, Illumination. A flare designed to provide a constant, uniform illumination level on the ground was patented in 1973 (Ref 1). Current flares burn with a constant candlepower output and when they descend, the illu-
Flare, Landing. See Reconnaissance and Landing Flare, under FLARE

Flare, Long Burning. A make-shift device, invented on the Korean front by C.J. Husch, was constructed from two empty shell cases filled with a mixture of Diesel fuel and gasoline and placed with an ordinary trip flare in a mortar container, previously filled to a certain level with Napalm, or jellied gasoline. When the flare was ignited, it set fire to the Napalm and heated the fuel (in shell cases) to the boiling point. The ensuing pressure forced burning vapor 6 to 10 feet into the air thru the perforations in the tops of the cases, and the brilliant yellow flame resulted, which lighted up surrounding terrain for more than 5 hours. Ref: Anon, Ordnance 36, No 190, 620 (1952)

Flare, Magnesium. A general term indicating a flare using Mg as the illuminating agent. Ref: Glossary of Ordn (1959), 119-L

Flare, Parachute. A pyrotechnic device attached to a parachute and designed to provide intense illumination for a short time. May be discharged from aircraft or from the surface. Ref: Glossary of Ordn (1959), 119-L

Flare, Parachute, Hand Fired. A complete self-contained device which is fired from the hand, and which provides a parachute borne pyrotechnic light. Ref: Glossary of Ordn (1959), 119-L

Flare Pistol, Pyrotechnic Pistol or Very Pistol. A single shot device designed specifically for projecting pyrotechnic signals. This item may or may not be provided with a method of mounting to an adapter. Ref: Glossary of Ordn (1959), 213-R (Pistols, Pyrotechnic)

Flares, Pyrotechnic for Cloud Seeding. Electrically or percussion-initiated flares, called "nuclei generators", are being used to disperse nucleating silver iodide and salt particles into clouds as a means of altering precipitation or controlling hailstorms, fog, lightning, violent hurricanes and tornadoes. Custom-made flares range from 2 to 18 inches in length; longer ones have 1 1/2 inch diameter. By controlling the chemical properties of the pyrotechnic mix, maker controls composition, burning rate and temp of combustion. Burning times range from under 45 seconds to 20 minutes. One item produces up to 25 grams of effective nuclei per minute for 4 1/2 minutes. A single gram of silver iodide can form billions of small ice crystals when sprayed into a cloud holding supercooled water droplets. Such crystals grow and fall of their own weight as snow or rain, depending on temps below the nucleating area. Clouds that harbor large water droplets are fertile for seeding; droplets form from molecules when the volume of molecules exceeds a certain critical radius, and when enough of them collide simultaneously. Maker's first field trial seeded warm clouds with salt nuclei to disperse fog; experiment increased visibility by as much as one mile. Flares can be fired from aircraft wing racks, or a standard Very pistol. Refs: 1) Olin-Mathieson Chemical Corp, 460 Park Ave, New York, NY 10022 2) Expls&Pyrots 1(6)(1968)
Flare, Reconnaissance. A former term for an aircraft flare used in air reconnaissance to light up the ground
Ref: Glossary of Ordn (1959), 119-L & R

Flare, Surface. See under Flare, Float and Flare, Surface

Flare System, Pyrotechnic. Experimentation with an advanced pyrotechnic flare system at Picatinny Arsenal, as reported in a technical paper at the 1970 Army Science Conference, indicates it offers several advantages over solid flares in current use. The system uses gas and thus has the advantage of on-off control, in contrast to solid flares which, once ignited, have to burn out or be extinguished and cannot be used again. Using a mixture of gases to produce bright white flames, the system permits illumination levels and burning times to be varied readily, and it has a time range of a fraction of a second to hours. Most solid flares burn only a short time.

While solid flares are smoky and therefore subject to wind and other weather conditions, the pyrotechnic system is relatively free of particulate matter and can be made directional. In testing, directional light efficiencies have been increased 12 times by using an aluminum reflector to produce efficiencies of one-quarter to one-half million candleseconds per gram.

Another advantage of gaseous systems is that they do not require atmospheric oxygen. The reproducible, homogeneous mixtures can be used and stored for long periods at high and low temperatures without loss of efficiency. Gas systems, which can be used on the ground or dropped by a parachute, require a burner, two tanks and an emitter. They can be ignited by remote control, either by electric fuse or an electric spark

Flare, Tow-Target. See Colored Tow-Target Flare, M50, under FLARE

Flare, Tree-Suspended. See under FLARE

Flares, Trip. See under FLARE

Flash. A sudden, transient outburst of flame or light, which may also be defined as a sudden luminous temporary flame
Refs: 1) Hackl's Dict (1946), 344-R
2) "The American College Dictionary", Random House, NY (1952), 460-L

Flash. NOLTR 1111 (1952), p 252 refers to the method of initiating an explosive loaded element by heat or flame from another element

Flash-Across, Heat-Pulse and Hypervelocity Phenomena, in Detonation. See Vol 4, pp D348-R & D349-L

Flash and Flame. When Lead Azide was shot in a non-explosive atmosphere, an intense luminosity was produced. This light emission was greatest in gas of low molecular specific heat, where the latter does not increase with temperature. The luminosity decreases the greater the specific heat and the temperature coefficient. The following gases were examined and found to have this decreasing order of luminosity: N₂ + H₂, CO₂, acetylene & butane. The effect was also observed to increase with the density of the surrounding gas, eg, H₂, N₂, O₂, Cl₂ or He, Ne, A & Kr. The luminosity was described as very feeble in H₂ or He. The explosion of 0.4 ml of a 3:1 mixture of TNM-toluene in argon gave a flash lasting under 5 microseconds with a brilliancy of 2.5-10 million candles. The effect was attributed to heating of the gas by adiabatic compression by the exlin wave and to the dissociation of molecules and
ionization of atoms. The increase in the series He, Ne, A, Kr followed the order of decreasing ionization potential. The formation of atomic oxygen and of ionized gases can be a factor in safety of expls in gassy coal mines
See Vol 3, p C448-R, Problems 1 and 2
Refs: 1) A. Michel-Lévy & H. Muranov, CR 198, 2091–3 (1934) & CA 28, 4907 (1934)
3) Ibid, 200, 924–6 (1935) & CA 29, 3160 (1935)

Flashback. Same as Backflash or Flareback described in Vol 2, pp B2-R & B3-L

Flashback Fuze. See Fuze, Spitback

Flashback (or Spitback) Tube. A tube attached to the truncated apex of a shaped charge liner, ordinarily extending thru the point of initiation to a detonator at the base of the explosive charge. Thru this tube the detonating impulse is transmitted from the point of initiation to a detonator at the base of the explosive charge.
Ref: Glossary of Ordn (1959), 270-R (Spitback Tube)

Flashbomb. See Photoflash Bomb, under Bombs, Pyrotechnic in Vol 2, p B229-L

Flash Charge. A readily ignitable explosive charge used in ignition elements of electric primers and detonators. Its function is usually to ignite a subsequent charge of lesser sensitivity and greater brilliance.
Ref: Glossary of Ordn (1959), p 65-L (Charge, Flash)

Flash Charge of Electric Squib. Its compn is DADNP (JAN-D-552) 20±2%, KClO₃ (MIL-P. 150C Grade I, Class C) 60±5%, powdered wood charcoal (JAN-C-178A) 15% 2%, Nitrostarch (N 12.75% min) 5±0.5%. Another compn is DADNP 19%, KClO₃ 66%, powdered wood charcoal 13%, Nitrostarch (N 12.75%) 2% (moisture 0.3% max). The 2nd of these mixts was analyzed at Picatinny Arsenal by the following methods:
Moisture. Transfer an accurately weighed portion of approx 1 g of the flash charge compn to a tared moisture dish 2 inches in diameter. Place the moisture dish and contents in a drying oven at 80°–85°C for 2 hours, cool in a desiccator and weigh. Calculate the loss in weight of the dish and contents to percent moisture in the sample.

Percentage of moisture = \( \frac{A - B}{W} \times 100 \)
where: A = loss in wt of moisture dish & contents in grams
W = wt of sample in grams on a dry basis
Diazodinitrophenol (DADNP). Transfer an accurately weighed portion of approx 1 g of the sample to a 250ml beaker and add 150ml of ethylene chloride. Heat the beaker and contents on a steam bath for 2 hrs with occasional stirring. Filter the contents of the beaker with the aid of a tared medium-sized porous-glass crucible and suction. Wash the beaker and residue in the crucible with boiling ethylene chloride until the filtrate coming thru the crucible is no longer colored yellow. Dry the crucible and residue in an oven maintained at 80°±5°C for 2 hours, cool in a desiccator and weigh. Calculate the percentage of Diazodinitrophenol in the sample on a dry basis as follows:

Percentage of DADNP = \( \frac{(A - B)}{W} \times 100 \)
where: A = wt of glass crucible and sample in grams
B = wt of glass crucible and residue in grams
W = wt of sample in grams on a dry basis
C = percent solubility of DADNP in ethylene chloride obtd as follows!
Place 0.1900±0.0010g of the dry Diazodinitrophenol from the lot used in the manufacture of the flash charge composition being analyzed in a 250ml beaker and add 150ml of ethylene chloride. Heat the beaker and contents on a steam bath for 2 hours with occasional
stirring. Filter the contents of the beaker with the aid of a tared medium-sized porous-glass crucible. Wash the beaker and residue in the crucible with hot ethylene chloride until the filtrate coming thru the crucible is no longer yellow in color. Dry the crucible and residue in an oven maintained at 100°C ± 5°C for 1 hr, cool in a desiccator and weigh. Calculate the loss in weight of the crucible and contents to percent solubility of DADNPh in ethylene chloride. This value is represented by the letter "C" given in the equation for calculating the percentage of DADNPh. This solubility was found to be 97.26% as determined on a batch of DADNPh. Use this value of 97.26% except in cases of non-compliance, dispute or question. In such cases use the value determined as described above.

Remark:

a. In connection with developing a method for the determination of the DADNPh content, it was found that DADNPh was not completely soluble in ethylene chloride solution and that this insolubility adversely affected the accuracy of the DADNPh determination. Therefore, it was considered advisable, in the method for the determination of the DADNPh content of the flash charge compn., to prescribe a correction equivalent to the solubility of the DADNPh. This solubility was found to be 97.26% when determined using one lot of DADNPh purchased from Hercules Powder Co. It is recognized that the solubility value of 97.26% may be significantly different for different lots of DADNPh. However, because of the non-availability of a sufficient number of different lots of DADNPh, used in the flash charge compn., no addnl work was done to establish the reliability of this solubility value or to determine whether a solubility value could be established which is invariant of the different lots of DADNPh used. In this connection it is intended that, in the course of the analysis of samples of flash charge compn., the solubility will be detd and recorded, whenever practicable, using various lots of DADNPh.

Nitrostarch. Extract the dry residue obtained in the above determination with ten 5ml portions of hot water, stirring the residue in the crucible after the addition of each portion before applying suction. Dry the crucible and residue obtained after the water extraction of the potassium chlorate with ten 5ml portions of hot acetone, stirring the residue in the crucible after the addition of each portion before applying suction. Dry the crucible and residue in an oven maintained at 100°C ± 5°C for 2 hours, cool in a desiccator and weigh. Calculate the percentage of Nitrostarch in the above sample on a dry basis as follows:

\[
\text{Percentage of NS} = \frac{100 (A - B)}{W}
\]

where: \( A \) = wt of glass crucible & residue before extraction with acetone, in grams

\( B \) = wt of glass crucible & residue after extraction with acetone, in grams

\( W \) = wt of sample in grams on a dry basis

Powdered Wood Charcoal. From the wt of the glass crucible and residue after extraction with acetone and the wt of the glass crucible calculate the percentage of powdered wood charcoal on a dry basis as follows:

\[
\text{Percentage of wood charcoal} = \frac{100 (A - B)}{W}
\]

where: \( A \) = wt of glass crucible & residue after extraction with acetone, in grams

\( B \) = wt of glass crucible in grams

\( W \) = wt of sample in grams on a dry basis

Potassium Chlorate. Calculate the percentage of potassium chlorate in the sample on a dry basis by subtracting from 100 the combined percentages of DADNPh, Nitrostarch and powdered wood charcoal.

Ref: J. Campisi, "Development of Methods of Analysis of the Flash Charge for Electric Squib", Report from the Chemical Laboratory of Picatinny Arsenal, Dover, NJ, Rept No. 126836, 14 July, 1949

Flash Composition-Lined Smokeless Propellant-Loaded Cartridge Shells. Shell shaped like shotgun shell, lined with a flash compn. (oxidizing agent and aromatic nitro compd.) loaded in grain colloided smokeless prop. (grain 0.240 inch dia. x 0.260 inch long). Flash compn causes uniform ignition suitable for starter for
internal combustion engines

**Flash Depressor.** A substance used to reduce the flash from a rocket motor
Ref: Glossary of Ordn (1959), 119-R

**Flash Distillation.** Distillation in which an appreciable proportion of a liquid is converted to vapor in such a way that the final vapor is in equilibrium with the final liquid
Ref: CondChemDict (1961), 499-R

**Flash Fuse.** A small explosive device similar in appearance to a detonator, but loaded with LE (low explosive), so that its output is primarily heat (flash). Usually electrically initiated, and employed to initiate action of pyrotechnic devices and rocket propellants. It is one of the *squibs*.
Ref: Glossary of Ordn (1959), 272-R (under Squib)

**Flash Hider or Muzzle Flash Suppressor** (Dämpfer, in Ger). A metallic cone and/or flat disks which are attached to the muzzle of a gun to conceal the flash when the gun is fired and to prevent temporary blindness of the crew while firing
Ref: 1) Glossary of Ordn (1959), p 119-R

**Flash Photography Without Battery.** In order to overcome the failure problems of contacts and batteries in ordinary flash cubes, Sylvania Co invented before 1970 a flashcube, called "Magicube" which is percussion activated. Its reliability is estimated at 99.7%. The flashcube works as follows:
   An initiating composition is coated on a wire centered in the tube, the wire acting as an anvil for this percussion initiating action.

The mechanical blow is provided by a torsion spring in the form of a hair pin that is triggered by a pin in the camera. When the picture is taken, the shutter button also pushes up the flashcube pin. The pin lifts the torsion spring from its latch so that the free spring end (the striker) strikes the outside of the metal tube to squeeze the initiating compn between deformed tube and wire anvil. Thus ignited the initiating compn flashes the light-producing zirconium mix in the lamp. Less than 0.2 inch-ounces of energy is required to lift the striker from the latch. It takes 0.3 milliseconds for the striker to travel from latch to tube. The striker develops energy from its spring action in excess of 3 inch-ounces. The cube consists of four lamps, each having its own spring striker.

The accompanying drawing is taken from the basic US patent 3533063. Pertinent call-outs are: (2) lamp envelope, (8) initiating assembly, (10) metal tube, (12) wire anvil,
(14) initiating compn, (22) protuberances designed to center the wire in the tube and to prevent the tube from touching the initiating compn, (26) crimp in tube to anchor the wire. Several initiating compns were patented, two are as follows:

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<tr>
<td></td>
<td>Zirconium</td>
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</tr>
<tr>
<td></td>
<td>Stabilized red phosphorus</td>
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<td></td>
<td>Sulfur</td>
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<tr>
<td></td>
<td>Sulfur</td>
<td>0.03</td>
</tr>
</tbody>
</table>

The basic construction has been modified in addl patents. One change added a refractory bead in the top of the wire (inside the lamp) to prevent burn thru and to disperse the hot particles of initiating material. Addl patents covering the initiation of the Magicube are: 3535064, 3540819, 3540820, 3597603, 3597604, 3602618, 3625641, 3667992, 3699021, 3700377, 3730569, 3734679


Flashes, Ignition and Propagation of. Flash radiographs taken by Hershkowitz (Ref) after initiation of a small quantity of expl centrally located in a case contg oxidant/metal (K perchlorate/atomized Al) compn show an expanding bubble of gaseous products, surrounded by an expanding spherical shell of compressed compn. High-speed framing camera photographs of the test item indicate ignition occurs at the outside periphery of the spherical shell of compn as a result of impact of this shell with the case and by flow of thermal energy during the period of case deformation

The interrelation of expl, compn, and case parameters in determining oxidant/metal flash performance are discussed qualitatively. Steps necessary to achieve a quantitative theory are outlined


Flashing Bullets. Bullets, producing flash of light on impact with a target to indicate the point hit, are charged with a compn contg Al and KClO₃, as for instance: Al 40, KClO₃ 30, TNT 20, Sn(NO₃)₂ 6 & glass 4%

Refs: 1) W.H. Buell, BritP 20307(1914) & CA 10, 694(1916) 2) W.H. Buell, USP 1242879(1917) 3) W.H. Buell, USP 1242900(1917) & CA 12, 225(1918) 4) P.P. Alexander, USP 2611316(1952) & CA 47, 5086(1953)

Flashing of Explosive Substances. The flashing characteristics of expl substances is not detd by the relation betw the bp and flash point. On rapid heating to high temp some expls show flameless decomp instead of a flash because of the small concn of the decomp products at the bp. It is these decomp products which are responsible for self-inflammation. Vapors of expls which have a much higher temp of self-inflammation than the bp, decompose without a flash; however at a higher temp, self-inflammation takes place again. Values for bp at 2mm (expl) , 50mm (expd) and 760mm (most probable value), ignition temp and latent heat of vaporization (cal/mol) for several expls are: MeNO₃ 5°, 66°, 4000; C₂H₆(NO₃)₃ 70°, 125°, 197±2°, 195-200°, 6500; TNT 190°, 245-250°, 300±10°, 295-300°, 10700; PA(Picric Acid) 195°, 255°, 325±10°, 300-310°, 6900; TNB(Trinitrobenzene) 175°, 250°, 315±10°, 7600; PETN 160°, 180°, 200±10°, 215°, 17300; Nitroglycerin 125°, 180°, 245±5°, 200°, 7100. The ignition temp approx coincides with the bp at 760mm which indicates that inflammation is preceded by the formation of a large amt of vapor which ignites when heated. TNT, PETN or PA neither detonate nor burn in vacuo, probably because the bp in vacuo is not near the ignition temp.
Flashing Test. This test, designed to ascertain whether the ingredients of Black Powder are thoroughly incorporated, is conducted as follows:

Fill a small crucible (or a thimble) with the sample and by inverting transfer onto a piece of asbestos board.

Touch the sample with a red hot soldering iron and observe how the powder ignites and burns.

If the powder has been thoroughly blended it will "flash", or "puff off", giving only a very few sparks and leaving only some smoke marks on the board.

A badly blended powder will produce many sparks and will leave specks of undecomposed K nitrate and sulfur forming a dirty residue.

Powder that has been damaged by moisture will flash badly even if the ingredients had been carefully incorporated originally. This is because the saltpeter had passed partially into solution and segregated into crystals of comparatively large size.

Ref: Marshall 2(1917), 415-16

Flashless. Said of a propellant or propelling charge which does not produce a muzzle flash in the weapon for which intended.

Ref: Glossary of Ordn (1959), 119-R

Flashless Ballistite. Ballistite, a double-base propellant (See Vol 2, pp B8-9) can be made flashless by either incorporating Centralite and DNX oil with NG and NC or by mixing Centralite and NGu with NG and NC. The NG does not dissolve in the colloid but is distributed thru it in a state of fine sub-division. Ten or fifteen parts of NGu incorporated with 90 or 85 parts of pyrocatechol colloidal with ether-alcohol gives a mix which may be extruded thru dies and yields a flashless powder.

Ref: Davis (1943), 299

Flashless Charges. See under Flash-Reducing Agents

Flashless and Cool Explosive. See Nitroguanidine (NGu) under Guanidine and Derivatives

Flashless Cordites are described in Vol 3 of Encycl, pp C532-R to C533-R, but the description of Cordite N was not given. For this, see Refs 1 & 2

Ref: SACMS(Scientific Advisory Council of Ministry of Supplies), "Interior Ballistics", Philosophical Library, NY (1951), p 6

2 Vol 1 of Encycl, under "Albanite", p A119-R

Flashless Gunpowder. NC or NG-NG base propellant containing up to 25% 5-Aminotetrazole had substantially reduced flash and smoke, while ballistic potential and stability were not reduced.


Flashless Mortar-Type Sheet of Propellant.

Flashless mortar-type smokeless propellant with caloric value 900-1100cal/g is made from NC (12.2-13.4% N) 50-8, NG 12-44, cooling plasticizer 2-10, (O₂NOC₂H₄)₂N(NO₂) 0-35%, small amount of stabilizer, small amount desensitizer and small amount inorganic salt to aid ignition.

Thickness depends on burning time desired. Example of one compn used: NC (13.25% N) 55, NG 33.65, (C₆H₄)₂NH 0.6, o-C₆H₄(CO₂Et)₂ 9.5, KNO₃ 1.25 & Me cellulose 0.2 parts.

Ref: A.M. Ball, USP 2577298 (1951) & CA 46, 3764 (1952)

Flashless Nonhygroscopic (FNH) Propellant.

See Vol 2 of Encycl, p C32-R, middle of column, under CANNON PROPELLANT

Flashless Propellant "Albanite" (US Navy).

See Vol 1 of Encycl, p A119-R
Flashless Propellant of Gollwitz, called "G" Pulver (Ger) is mentioned in Vol 3 of Encycl, p C511-R under "Cool(or Cooled) Propellants". A complete description, including history, is given in Vol 5, p D1535-R to D1537-R and in PATR 2510(1958), pp Ger 70-R & Ger 71-L

Flashless Propellant "Gudolpulver" (Ger). See Vol 5 of Encycl, pp D1537-R to D1538-R and PATR 2510 (1958), pp Ger 81-L & R

Flashless Propellant of Kincaid & McGill. Triple-base + non-vol plasticizers nitroxy-alkyl nitramines (See under Amines), polynitrate esters of poly(hydroxymethyl) cyclo-alkanones & poly(hydroxymethyl) cyclo-alkanols

Flashless Propellant for Naval Cannons. See "Albanite" in Vol 1, p A119-R

Flashless Smokeless Propellant of Barsky consisted of NC 75–93, DNT (or TNT) 5–15, plasticizer & flash suppressor 2–10%. Latter was an ester of fatty acid C_6 to C_14, such as TeGc caprylate, TeGc caprylate-caprate or Pi-Gc caprylate
Refl: G. Barsky, USP 2439281 (1948) & CA 42, 4349(1948)

Flashlight for Use in Photography. It is a brilliant white light, produced either by magnesium powder or by special bulbs. See Flash Photography in Vol 2 of Encycl, p C14-L & R, under CAMERAS

Flash Photography. See Vol 2, p C14-L & R, under CAMERAS, High-Speed Photographic

Flash Photolysis. A method of conducting photochemical reactions by high intensity illumination. The illumination is from a high intensity flash of 1000–10000 J obtained by discharging a bank of condensers thru a gas (A or Kr) discharge tube (quartz) (35μF at 8000V gives ca 1000 J for 10^{-4} sec). The gas discharge tube and a reaction tube are arranged in parallel and a lamp for illumination is located at one end of the reaction tube. A suitable spectroscope is located at the other end of the reaction tube. May be used showing changing in short lived intermediates with time. The references cited describe the chemistry of expl of H_2 or C_2H_2 with O_2

FLASH POINT (fl p) and FIRE POINT (fl p), Flash Point is defined in Bofors Laboratory Manual (Ref 1) as "the lowest temperature at which, under given conditions (type of apparatus, heating arrangement, etc) a liquid gives off flammable vapors which, when mixed with air under normal atmospheric pressure, flash on approaching a flame to them. Fire Point is defined and described in Item A, listed below

A. FLASH AND FIRE POINTS BY CLEVELAND OPEN CUP METHOD (COC). The Cleveland Open Cup Apparatus is described as Method 4294 (Sept 1955) of Federal Test Method Standard No 141a

The apparatus consists of a brass cup (See Fig F10), supported by a metal heating plate, ¼ inch thick and 6 inches in diameter (not shown here). In the center of the plate there is a plane depression 1/32 inch in depth, and of just sufficient diameter to fit the cup. There is also a circular opening 2-1/2 inches in diameter, cut thru the plate, centering with the center of the above-mentioned depression. The plate is covered with a sheet of hard asbestos board ½ inch thick, and of the same shape as the metal plate and with a hole cut in the center just to fit the cup. Heat may be supplied from any convenient source. The use of gas burner, electric heater, or alcohol lamp is permitted, but under no circumstances are
products of combustion or free flame allowed to come around the cup. The source of heat that does not produce local superheating shall be centered under the opening in the plate. If a flame heater is used, it shall be protected from drafts and excessive radiation by a shield that does not project above the level of the upper surface of the asbestos board.

Thermometer shall be an ASTM Open Flash-Type, graduated in either centigrade (−6° to +400°C) or Fahrenheit (+20° to +760°F) degrees and conforming to the requirements for thermometer 11C or 11F, respectively, as prescribed in ASTM E1

Procedure

1. The thermometer shall be suspended or held in a vertical position by any suitable device. The bottom of the bulb shall be ¾ inch (0.635 cm) from the bottom of the cup, and above a point halfway between the center and back of the cup.

2. The cup shall be filled with the sample to be tested in such a manner that the top of the meniscus is exactly at the filling line at room temperature. The surface of the sample shall be free from bubbles. There shall be none of the sample above the filling line or on the outside of the apparatus.

3. The test flame shall be approx 5/32 inch (0.397 cm) in diameter.

4. The test flame shall be applied as the temperature read on the thermometer reaches each successive 5°F (2.8°C) mark. The flame shall pass in a straight line (or on the circumference of a circle having a radius of at least 6 inches) across the center of the cup and at right angles to the diameter passing through the thermometer. The test flame shall, while passing across the surface of the sample, be in the plane of the upper edge of the cup. The time for the passage of the test flame across the cup shall be approx 0.1 second.

5. The sample shall be heated at a rate not exceeding 30°F (16.7°C) per minute temperature rise, until a point is reached approx 100°F (55.6°C) below the probable flash point of the sample. Thereafter the rate of heating shall be decreased, and for at least the last 50°F (27.8°C) before the flash point is reached, the rate shall be not less than 9°F (5°C) nor more than 11°F (6.1°C) per minute.

6. Flash Point. The flash point shall be taken as the temp read on the thermometer when a flash appears at any point on the surface of the sample. The true flash must not be confused with a bluish halo that sometimes surrounds the test flame.

7. Fire Point. After determining the flash point, the heating shall be continued at the specified rate of 9° to 11°F (5° to 6.1°C) per minute, and application of the test flame shall be made at the specified intervals until the sample ignites and continues to burn for a period of at least 5 seconds. The method of application of the flame shall be the same as for flash point. The temp read at the time of the flame application which causes burning for a period of 5 seconds or more shall be recorded as the fire point.

Notes:

a. The following facilities are of great importance and should be carefully observed. Laboratory conditions shall be such that flash and fire point tests are made in a room...
or compartment free from air currents. Care shall be observed to avoid disturbing the vapors evolved in the cup while heating, either by careless breathing or unnecessary movements near the flash cup. It is desirable that the room or compartment be darkened sufficiently so that the flash can be readily detected.

b. Results shall not differ from each other by more than the following:

<table>
<thead>
<tr>
<th>Flash or fire point (°F)</th>
<th>175 to 550</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 550</td>
<td>10</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

**FLASH POINT OF LIQUIDS BY TAG OPEN CUP APPARATUS** (ASTM Designation D1310-72)

1. Scope

1.1 This method covers the determination of flash points by Tag open-cup apparatus of liquids having flash points between 0 and 325 F (−17.8 and 168 C).

1.2 This method, when applied to paints and resin solutions which tend to skin over or which are very viscous, gives less reproducible results than when applied to solvents.

Note 1: A value of 80 F (26.7 C) determined by this method has been established by the US Department of Transportation as the maximum value for classifying liquids as flammable. Materials having a flash point at or below 80 F (26.7 C) must be identified with an ICC Red Label for interstate shipment by common carrier within the United States. In addition, certain regulations on types of shipping containers apply to materials flashing at 20 F (−6.7 C) or below.

For details of ICC shipping regulations, see Tariff No 19, issued August 5, 1966, by T.C. George, Agent, 63 Vesey St, New York, NY 10007, publishing Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles by Land and Water in Rail Freight Service and by Motor Vehicle (highway and water) including Specifications for Shipping Containers. (Regulations for transportation in rail express and rail baggage services are also included for information)

Note: Shipping regulations are now updated annually by the Department of Transportation. Be sure to use the latest regulation. For more information on shipping regulations, see EXPLOSIVES, NONMILITARY (COMMERCIAL) (Papers and Reports Listed in Chronological Order), Item 87, "On Shipping Explosives", this Vol of Encycl, p E468

2. Apparatus (Appendix A1)

A1.1 Tag Open-Cup Tester, shown in Fig F11. It consists of the following parts, which must conform to the dimensions shown, and have the additional characteristics as noted:

**Metric Equivalents**

<table>
<thead>
<tr>
<th>in.</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-13/16</td>
<td>71.4</td>
</tr>
<tr>
<td>3-3/16</td>
<td>80.9</td>
</tr>
<tr>
<td>6-7/8</td>
<td>174.6</td>
</tr>
</tbody>
</table>
A1.1.1 Copper Bath, preferably equipped with a constant-level overflow so placed as to maintain the bath liquid level 1/8 inch (3.2mm) below the rim of the glass cup.

A1.1.2 Thermometer Holder, supplied with the tester as shown in Fig. It shall support the thermometer firmly in a vertical position. Thermometers must conform to ASTM Specification.

A1.1.3 Glass Test Cup is of molded clear glass, annealed, heat-resistant, and free from surface defects.

A1.1.4 Leveling Device, or gage, for proper adjustment of the liquid level in the cup. This shall be made of polished aluminum or stainless steel 1/8 inch (3.2mm) 0.125±0.003 inch (3.22±0.07mm) thick, with two projections for adjusting the liquid level in the glass cup to exactly 1/8 inch below the top edge or rim of the cup. This leveling device may also be used to adjust the size of the test flame and for gauging the height of the taper above the edge of the cup.

A1.1.5 "Micro" or Small Gas Burner, of suitable dimensions for heating the bath. A screw clamp may be used to help regulate the gas. A small electric heater controlled by a variable power transformer may be used.

A1.1.6 Ignition Taper, which is a small, straight, blow-pipe type gas burner. The tip of the taper should be approx 1/16 inch (1.6mm) in diam and the orifice should be 1/32 inch (0.8mm) in diam. The ignition taper should be maintained in a fixed horizontal plane above the test cup by means of a swivel device so that the test flame passes on the circumference of a circle having a radius of at least 6 inches (152.4mm).

A1.1.7 Draft Shield, consisting of two rectangular sheets of noncombustible material, 24 by 28 inches (610 by 710mm), are fastened together along the 28-inch (710mm) side, preferably by hinges. A triangular sheet, 24 by 24 by 34 inches (610 by 610 by 860mm), is fastened by hinges to one of the lateral sheets (to form a top when shield is open). The interior of the draft shield shall be painted a flat black. A draft-free fume hood may be used.

Two 500-ml flasks with rubber stoppers

6. Procedure

6.1 For flash points below 55°F (13°C) or above 140°F (60°C), use as bath liquid a 1 + 1 mixture of water and ethylene glycol. For flash points between 55°F (13°C) and 140°F (60°C), either water or water-glycol mixture may be used as bath liquid (Note 4). The temp of the liquid in the bath shall be at least 20°F (11°C) below the expected fl p at the time of introduction of the sample into the test cup. Do not cool the bath liquid by direct contact with carbon dioxide or "dry ice". Place the test cup in position in the bath.

Note 4: Due to possible difficulty in maintaining the prescribed rate of temp rise and due to the formation of ice on the lid, results by this method for samples having fl p's below 32°F (0°C) may be somewhat unreliable. Trouble due to ice formation on the slide may be minimized by carefully lubricating the slide shutter with high-vacuum silicone lubricant.

6.2 Using a graduate and taking care to avoid wetting the cup above the final liquid level, measure 50±0.5ml of the sample into the cup, both the sample and graduate being precooled, if necessary, so that the sample temp at the time of measurement will be 80±10°F (27±5.6°C) or at least 20°F (11°C) below the expected flash point, whichever is lower. It is essential that the sample temp be maintained at least 20°F (11°C) below the expected fl p during the transfers from the sample container to the graduate and from the graduate to the test cup. Destroy air bubbles on the surface of the sample. Wipe the inside of the cover with a clean cloth or absorbent tissue paper; then attach the lid, with the thermometer in place, to the bath collar.

6.3 Light the test flame, adjusting it to the size of the small bead on the cover. Operate the mechanism on the cover in such a manner as to introduce the test flame into the vapor space of the cup, and immediately bring it up again. The time consumed for the full operation shall be about 1 sec, or the time required to pronounce distinctly the words "thousand and one". Avoid any jerkiness in the operation of depressing and raising the test flame.
6.4 Flash Points Below 140 F (60 C). If the fl p of the sample is known to be below 140 F (60 C), apply and adjust the heat so that the temp of the sample will rise at a rate of 2 F (C)/min ± 6 secs. When the temp of the sample in the test cup is 10 F (5.6 C) below its expected fl p, apply the test flame in the manner just described in 6.3, and repeat the application of the test flame after each 1 F (0.6 C) rise in temp of the sample.

6.5 Flash Points at or above 140 F (60 C). If the fl p of the sample is known to be 140 F or higher, apply and adjust the heat so that the temperature of the sample will rise at a rate of 5 F (3 C)/min ± 6 secs. When the temp of the sample in the test cup is 10 F (5.6 C) below its expected fl p, apply the test flame in the manner described in 6.3, and repeat the application of the test flame after each 2 F (1 C) rise in temperature of the sample, at each temperature reading that is a multiple of 2 F (1 C).

6.6 When the test flame application causes a distinct flash in the interior of the cup, observe and record the temperature of the sample as the fl p. Do not confuse the true flash with the bluish halo which sometimes surrounds the test flame at applications immediately preceding the actual flash.

6.7 Discontinue the test and remove the source of heat. Lift the lid and wipe off the thermometer bulb. Remove the sample cup, empty, and wipe dry.

6.8 If, at any time between the first introduction of the test flame and the observation of the flash point, the rise in temp of the sample is not within the specified rate, or if the actual flash point differs from the expected flash point by an amt greater than 4 F (2 C), discard the result and repeat the test, adjusting the source of heat to secure the proper rate of temp rise and/or using a modified "expected flash point", as required.

Note 5: Never make a repeat test on the same portion of sample once used—always take a fresh portion of sample for each test.

7. Correction for Barometric Pressure

7.1 Observe and record the barometric pressure at the time of the tests. When the pressure differs from 760mm Hg, correct the fl p by means of the following equation, the corrected fl p being recorded to the nearest whole number.

Corrected flash point = F + 0.06(760 - P)

3. Summary of Method

3.1 The sample is placed in the cup of a Tag Open Tester, and heated at a slow but constant rate. A small test flame is passed at a uniform rate across the cup at specified intervals. The flash point is taken as the lowest temp at which application of the test flame causes the vapor at the surface of the liquid to flash. In the case of less volatile materials, the vapors may ignite but not continue to burn. With more volatile materials, the fl p and fl p may occur simultaneously.

4. Apparatus — described under 2.

5. Materials

5.1 Water—Glycol Solution (1 + 1), for flash points from 0 to 200 F (−17.8 to 93.3 C).

5.2 Solid Carbon Dioxide-Acetone or other coolant.

5.3 Silicone Fluid, inert, high-boiling, for fl p’s from 200 to 325 F (93.3 to 168 C).

5.4 n-Heptane, for determination of fl p’s from 0 to 60 F (−17.8 to 15.6 C). See Appendix A2 for specifications.

5.5 p-Xylene, for determination of fl p’s from 60 to 200 F (15.6 to 93.3 C). See Appendix A2 for specifications.

5.6 Isopropyl Alcohol, for determination of fl p’s from 60 to 200 F (15.6 to 93.3 C). See Appendix A2 for specifications.

5.7 Diethylene Glycol, for determination of fl p’s from 200 to 325 F (93.3 to 168 C). See Appendix A2 for specifications.

Appendix A2

A2.1 Specifications for n-Heptane; Flash Point Check Grade

A2.1.1 n-Heptane shall conform to the following requirements:

Density at 20 C — 0.6830±0.00015 when determined in accordance with Method D1217
Refractive Index nD 20 C — 1.38770±0.00015 when determined in accordance with Method D1218

Freezing Point — −90.71 C min, when determined in accordance with Method D1015
Distillation (760mm) — 50% recovered at 98.427±0.025 C. Differential, 80% recovered minus 20% recovered — 0.20 C, max.
Note: For equipment and method used, see C.S. Dussinger et al in JResearchJMSB NatBurStandards 44(3), 309–10 (1950)
A2.2 Specifications for p-Xylene; Flash Point Check Grade

A2.2.1 p-Xylene shall conform to the following requirements:
Specific gravity 13.56/15.56 C = 0.860 min, 0.866 max
Boiling range - 2 C max from start to dry point, when tested in accordance with Method D 850, or the Method D 1078. The range shall include the boiling point of pure p-xylene, which is 138.35 C (281.03 F)

Purity - 95% min (Freezing point of 11.23 C min) calculated in accordance with Method D 1016, from the experimentally determined freezing point, measured by Method D 1015 A2.3 Specifications for Isopropanol 91%: Flash Point Check Grade
A2.3.1 Isopropanol shall conform to the following requirements:
Specific gravity - 0.8175 to 0.8185 at 20/20 C as determined by means of a calibrated pycnometer
Distillation range - shall entirely distill within a 1.0 C range which shall include the temp 80.4 as determined by Method D 1078

A2.4 Specifications for Diethylene Glycol; Flash Point Check Grade
A2.4.1 Diethylene glycol shall conform to the following requirements:
Specific gravity - 1.1170 to 1.1200 at 20/20 C as determined by means of a calibrated pycnometer
Distillation range - shall entirely distill within a 5.0 range which shall include the temp 245.8 C as determined by Method D 1078
Water - not more than 0.2% as determined by Method D 1364

6. Assembly and Preparation of Apparatus
6.1 Place the tester in a level position on a solid table free of vibration, in a location free of perceptible draft, and in a dim light. Maintain a room temp of 75±5 F (24±3 C) throughout the test
6.2 Adjust the horizontal and vertical positions of the taper so that the jet passes on the circumference of a circle having a radius of at least 6 inches (152.4 mm). The jet should pass across the center of the cup at right angles to a diam passing thru the thermometer, and in a plane 1/8 inch (3.2 mm) above the upper edge of the cup as measured from the center of the orifice

6.3 Using the leveling device as a gage, adjust the height of the taper so that the center of the orifice is exactly 1/8 inch (3.2 mm) above the top edge of the glass cup when it is in place. It is imperative that this adjustment be made as accurately as possible. Raising or lowering the taper can be achieved by bending it slightly or preferably by adding and removing thin metal shims as required from between the taper and the vertical supporting member of the swivel holder (See Note 7)

6.4 With the glass cup in place in the bath, adjust the thermometer holder so that the thermometer is supported firmly in a vertical position half way between the center and edge of the cup and the pivot of the taper. Place the thermometer so that the bottom of the bulb is 1/4 inch (6.4 mm) from the inner bottom of the cup

6.5 Set the draft shield around the tester so that the sides form right angles with each other and the tester is well toward the back of the shield

7. Procedure
7.1 Flash Points from 0 to 60 F (-17.8 to 15.6 C):
Note 2: Caution - Meticulous attention to all details relating to the taper, size of taper flame, rate of temperature increase, and rate of passing the taper over the sample is necessary for good results

7.1.1 Equip two 500-ml flasks with rubber stoppers thru which are inserted ASTM 33F thermometers. Cool a quantity of 1 to 1 water-glycol solution in one stoppered 500-ml flask to approx -20 F (-28.9 C) by immersing the flask in a solid carbon dioxide-acetone bath or other coolant. Use extreme care not to contaminate the water-glycol solution with either acetone or carbon dioxide

7.1.2 Pour the cooled water-glycol solution into the tester bath to a predetermined level 1/8 inch (3.2 mm) below the top when the cup is in place. An overflow pipe is desirable for controlling the liquid level in the bath

7.1.3 At the same time the water-glycol
coolant is being chilled, cool a portion of the sample to approx -10 F (-23.3 C) in the second stoppered 500-ml flask. If solid carbon dioxide and acetone or other volatile solvents are used as a coolant, extreme care must be exercised to avoid contamination of the sample. Cool the glass cup and place it in the bath. Position the appropriate thermometer as described in 5.4 and fill the cup with cooled sample to a depth approx 1/8 inch (3.2 mm) below the edge as determined by the leveling device.

7.1.4 Light the ignition flame and adjust it to form a flame of spherical shape matching in size the 5/32-inch (4.0 mm) sphere on the apparatus or the 5/32-inch hole in the leveling device.

**Note 3:** Remove all bubbles from the surface of the sample liquid before starting a determination.

7.1.5 Final adjustment of the sample level in the cup is made when the temperature is 20 F (11 C) below the anticipated flash point. Two trial determinations may be necessary to select the proper temperature at which to adjust the liquid level. A hypodermic syringe or medicine dropper provides a convenient means of adding or removing sample from the cup.

7.1.6 Allow the temperature of the sample to increase spontaneously without applying any heat until the rate of temperature rise decreases to 2°F (1 C)/min. At this point apply heat to maintain an increase in temperature at a rate of ±0.5 F (±0.25 C)/min.

**Note 4:** With viscous materials, this rate of heating cannot always be maintained.

7.1.7 Determine the approx flash point by passing the taper flame across the sample at intervals of 2°F (1 C). The first pass of the taper flame should be made immediately after the final adjustment of the sample level, as in 6.1.5. The time required to pass the ignition flame across the surface of the sample should be 1 sec. Each pass must be in one direction only and the taper should be kept in the “off” position at one or the other end of the swing, except when the flame is applied to the sample. In case the sample tends to “creep” over the edge of the cup, carefully wipe the edge with absorbent tissue to remove frost and liquid just prior to passage of the taper over the cup.

**Note 5:** When determining the flash point of viscous liquids and those liquids which tend to form a surface film, the following procedure is suggested: Insert to a depth of about 1/2 inch (12.7 mm) in approx a vertical position, the end of a stirring rod beginning about 15 sec before the taper is passed over the surface. Move the rod from side to side of the cup for three or four complete passes following approx the path of the taper, remove, and make the test.

7.1.8 Continue with 7.4.

7.2 Flash Point from 60 to 200 F (15.6 to 93.3 C) (See Notes 2, 3, 4 and 5):

7.2.1 Run cold water, brine or water-glycol solution into the bath to a predetermined level which will fill the bath to 1/8 inch (3.2 mm) below the top when the cup is in place. The bath liquid should be at least 30 F (17 C) below the anticipated flash point.

7.2.2 If necessary, cool a portion of the sample to at least 20 F (11 C) below the anticipated flash point. Exercise adequate care to avoid contamination of the sample with coolant liquid or vapors. Fill the glass cup with the cooled sample to a depth approx 1/8 inch (3.2 mm) below the edge with the proper thermometer (See Table 1) positioned as described in 6.4.

7.2.3 For final adjustment of the sample level, see 7.1.5.

7.2.4 Light the ignition flame and adjust it as described in 7.1.4.

7.2.5 Apply heat to the liquid bath and adjust so that the temperature of the sample increases at a rate of ±0.5 F (±0.25 C)/min.

7.2.6 Determine the approx flash point by passing the taper flame across the sample at intervals of 2°F (1 C) as described in 7.1.7.

7.2.7 Continue with 7.4.

7.3 Procedure for Flash Points from 200 to 325 F (93.3 to 168 C) (See Notes 2, 3, 4 and 5):

7.3.1 Place a high-boiling inert silicone fluid in the bath to a predetermined level which will fill the bath to 1/8 inch (3.2 mm) below the top when the cup is in place.

7.3.2 With the appropriate thermometer (See Table 1) properly positioned (6.4), fill the glass cup with sample at room temperature to a depth slightly more than 1/8 inch (3.2 mm).
below the edge as determined by the leveling device.

**TABLE 1 Thermometers**

<table>
<thead>
<tr>
<th>For Tests</th>
<th>Below 40</th>
<th>At 40 to 120</th>
<th>Above 120</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F (4°C)</td>
<td>F (4 to 9°C)</td>
<td>F (9°C)</td>
</tr>
<tr>
<td>Use ASTM</td>
<td>57°F or</td>
<td>9°F or 9°C</td>
<td>9°F or 9°C</td>
</tr>
<tr>
<td>Thermometer*</td>
<td>57°C</td>
<td>57°F or 57°C</td>
<td></td>
</tr>
</tbody>
</table>

* Complete specifications for these thermometers are given in ASTM Specification E 1, for ASTM Thermometers.

7.3.3 For final adjustment of the sample level, see 7.1.5

7.3.4 Light the ignition flame and adjust it as described in 7.1.4

7.3.5 Apply full heat to the liquid bath and when the temperature of the sample reaches 190°F (87.8°C), adjust the heat input so that the temp of the sample increases at a rate of 2±0.5°F/ (1±0.25°C)/min.

*Note 6:* The heaters on some testers do not have sufficient capacity to maintain the proper rate of heating when the temperature approaches 250°F (121.1°C) or above. The heat input to the liquid bath may be increased if necessary by using a variable transformer to increase the voltage on the heater or by wrapping the bath with electrical heating tape. The application of suitable insulation to the outside of the bath to prevent heat loss is also permissible. The important factor is to maintain the rate of temp increase of the sample at 2±0.5°F/ (1±0.25°C)/min.

7.3.6 Determine the approximate flash point by passing the taper flame across the sample at intervals of 2°F (1°C) as described in 7.1.7

7.4 Recorded Test:

7.4.1 After the initial test to determine the approx flash point of the material, repeat the procedure by cooling a fresh portion of the sample, the glass cup, the bath solution, and the thermometer to more than 20°F (11°C) below the approx flash point. When the temp of the sample is exactly 20°F below the approx flash point, the center of the liquid level should be adjusted to 1/8 inch (3.2mm) below the upper edge of the cup as determined with the leveling device placed across the diam of the cup.

7.4.2 Resume heating, or allow the temp to rise spontaneously in the case of material flashing below 60°F (15.6°C). Following the instructions given in 6.1, pass the taper flame across the sample at two intervals of 5°F (3°C) and then at intervals of 2°F (1°C) until the flash point occurs.

7.4.3 Determine and record not less than three test values.

8. Standardization and Calculation

8.1 Flash Points from 0 to 60°F (−17.8 to 15.6°C):

8.1.1 Make at least five determinations of the flash point of standard n-heptane which meets the specifications set forth in Appendix A2. Average these values. If the average differs from 23°F (−4°C) by more than ±3°F (±1.7°C), adjust the height of the taper and repeat the standardization (Note 7).

8.1.2 Calculate the correction factor as follows:

\[ \text{Correction factor} = 23 - A \]

where: \( A \) = average observed flash point of n-heptane.

8.1.3 Apply this correction to all flash point determinations between 0 and 60°F (−17.8 to 15.6°C). Round off corrections to the nearest whole number according to Recommended Practice E 29.

8.2 Flash Points from 60 to 200°F (15.6 to 93.3°C):

8.2.1 Make determinations in triplicate on the flash point of standard p-xylene and of standard isopropyl alcohol which meet specifications set forth in Appendix A2. Average these values for each compound. If the difference between the values for these two compounds is less than 15°F (8.5°C) or more than 27°F (16°C), repeat the determinations or obtain fresh standards (Note 7).

8.2.2 Calculate a correction factor as follows:

\[ X = 92 - A \]
\[ Y = 71 - B \]

\[ \text{Correction} = \frac{(X + Y)}{2} \]

where: \( A \) = observed flash of p-xylene, and \( B \) = observed flash of isopropyl alcohol.

8.2.3 Apply this correction to all flash point dets between 60 and 200°F (15.6 and 93.3°C). Round off corrections to the nearest whole number according to Recommended Practice E 29.
8.3 Flash Points from 200 to 325 F (93.3 to 168 C):
8.3.1 Make at least five detms of the flash point of standard diethylene glycol which meets the specifications set forth in Appendix A2. Average these values and if the average differs from 295 F (146 C) by more than ± 10 F (± 5.5 C), adjust the height of the taper and repeat the standardization.
Note 7: The height of the taper arm is very important. Raising the taper 0.01 inch (0.25 mm) increases the flash about 2 F (11 C). Therefore, it is suspected that the taper arm has been jarred or bent, the apparatus should be recalibrated. Each unit of apparatus should have its calibration checked about once a week if in constant use, or on each occasion of use if used only occasionally.
8.3.2 Calculate the correction factor as follows:
Correction = 295 - A
where: A = average observed flash point of diethylene glycol
8.3.3 Apply this correction to all flash point determinations between 200 and 325 F (93.3 and 168 C). Round off corrections to the nearest whole number according to Recommended Practice E 29.
Note 8: The calibration procedure provided in this method will cancel out the effect of barometric pressure if calibration and tests are run at same pressure.
9. Report
9.1 The average of not less than three corrected recorded tests, other than the initial test, shall be reported to the nearest 1 F (0.5 C). Three multiple runs are acceptable for averaging if the difference between the extreme values does not exceed 7 F (4 C) (95% confidence level)
10. Precision ᵃ
10.1 The following criteria should be used for judging the acceptability of results between 0 and 200 F (−17.8 and 93.3 C) at a 95% confidence level:
10.1.1 Reproducibility — Two results (each the average of at least three detms) obtained by the same analyst will differ, on the average, by approx 1.5 F (0.8 C). They should be considered suspect if the difference exceeds 4 F (2.2 C).
10.1.2 Reproducibility — Two results (each the average of at least three detms) reported by analysts in different laboratories will differ, on the average, by approx 2.5 F (1.4 C). They should be considered suspect if the difference exceeds 7 F (4 C).
10.2 The following criteria should be used for judging the acceptability of results between 200 and 325 F (93.3 and 168 C) at a 95% confidence level:
10.2.1 Repeatability — Two results (each the average of at least three detms) obtained by the same analyst will differ, on the average, by approx 3.0 F (1.7 C). They should be considered suspect if the difference exceeds 9 F (5 C).
10.2.2 Reproducibility — Two results (each the average of at least three detms) reported by analysts in different laboratories will differ, on the average, by approx 4.0 F (2.2 C). They should be considered suspect if the difference exceeds 12 F (7 C).
10.3 On the basis of an interlaboratory test of the method using viscous, heavily-pigmented materials which tended to form a surface film, the within-laboratory standard deviation was found to be 3 F (1.7 C) and the between-laboratory standard deviation was found to be 7 F (3.9 C). Based on these standard deviations, the following criteria should be used for judging the acceptability of results at a 95% confidence level:
10.3.1 Repeatability — Two results, each the mean of three detms, obtained by a single operator on different days should be considered suspect if they differ by more than 9 F (5 C).
10.3.2 Reproducibility — Two results, each the mean of three detms, obtained by operators in different laboratories should be considered suspect if they differ by more than 24 F (13.3 C)
FLASH POINT OF LIQUIDS BY TAG CLOSED TESTER (ASTM Designation D56-70)
1. Scope
1.1 This method covers the detm of the flash point, by Tag closed tester, of liquids with a viscosity of below 45 SUS at 100 F (37.8 C) and a fl pt below 200 F (93 C) except cut-back asphalts and those liquids which tend to form a surface film under test conditions.
Note 1: For the closed cup fl pt of liquids with
FIG F12  TAG CLOSED TESTER
a viscosity of 45 SUS or more at 100°F (37.8°C) or a fl pt of 200°F or higher, use ASTM Method D 93, Test for Flash Point by Pensky-Martens Closed Tester. For cut-back asphalts refer to ASTM Method D 1310, Test for Flash Point of Liquids by Tag Open-Cup Apparatus

2. Summary of Method

2.1 The sample is placed in the cup of the tester and, with the lid closed, heated at a specified constant rate. A small flame of specified size is directed into the cup at regular intervals. The fl pt is taken as the lowest temp at which application of the test flame causes the vapor above the sample to ignite.

3. Apparatus

3.1 Tag Closed Tester — The apparatus is shown in Fig 11 and described in detail in Appendix A1. Refer to Appendix A2 for directions for checking the condition and operation of the tester.

3.2 Shield — A shield 18 inches (460mm) square and 24 inches (610mm) high, open in front, is recommended.

3.3 Thermometers — For the test cup thermometer, use one as prescribed in Table 1. For the bath thermometer, any convenient type which has adequately open scale covering the required range may be used; it is often convenient to use the same type of thermometer as used in the test cup.

Note 2: Whenever thermometers complying with ASTM requirements are not available, thermometers complying with the requirements for the Institute of Petroleum thermometer IP 15F PM-Low may be used.

Note 3: There are automatic flash point testers available and in use which may be advantageous in the saving of testing time, permit the use of smaller samples, and other factors which may merit their use. If automatic testers are used, the user must be sure that all of the manufacturer’s instructions for calibrating, adjusting and operating the instrument are followed. In any cases of dispute, the fl pt as detd manually shall be considered the referee test.

4. Sample

4.1 Erroneously high flash points may be obtained if precautions are not taken to avoid the loss of volatile material. Containers shall not be opened unnecessarily and transfers shall not be made unless the sample temp is at least 20°F (11°C) below the expected fl pt. Samples in leaky containers shall be discarded.

5. Preparation of Apparatus

5.1 Support the tester on a level steady table. Unless tests are made in a draft-free room or compartment, surround the tester on three sides by the shield for protection from drafts. Tests made in a laboratory draft hood or near ventilators are not to be relied upon.

5.2 Gas is recommended for the test flame. If gas is not available, insert a wick of cotton in the burner tip, place small quantity of cotton waste in the chamber to which the burner tip is attached, and fill the chamber with signal, sperm, or lard oil.

8. Precision

8.1 The following criteria should be used for the acceptability of results (95% probability)

8.1.1 Repeatability — Duplicate results by the same operator should not be considered suspect unless they differ by more than the following amounts:

<table>
<thead>
<tr>
<th>Flash Point</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 55°F (13°C)</td>
<td>6°F (3.3°C)</td>
</tr>
<tr>
<td>55°F (13°C) to 139°F (59°C)</td>
<td>4°F (2.2°C)</td>
</tr>
<tr>
<td>140°F (60°C) to 199°F (93°C)</td>
<td>6°F (3.3°C)</td>
</tr>
</tbody>
</table>

FLASH POINT OF LIQUIDS BY PENSKY-MARTENS CLOSED TESTER
(ASME Designation E134–68)

1. Scope

1.1 This specification defines the Pensky-Martens Closed Flash Tester as used in ASTM Method D93, Test for Flash Point by Pensky-Martens Closed Tester.

Note 1: The values stated in US customary units are to be regarded as the standard. The metric equivalents of US customary units may be approximate.

2. Apparatus Assembly

2.1 A typical assembly of the apparatus, gas heated, is shown in Fig F13. The apparatus shall consist of a test cup, lid, and stove conforming to the requirements given in Sections 3 to 5.
FIG F13 Pensky-Martens Closed Tester

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<td>B</td>
<td>41.94</td>
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</tr>
<tr>
<td>C</td>
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<td>0.062</td>
</tr>
<tr>
<td>D</td>
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</tr>
<tr>
<td>E</td>
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<td>2.253</td>
</tr>
<tr>
<td>F</td>
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<td>0.25</td>
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</table>
FIG F14  Test Cup

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<tr>
<td>B</td>
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<td>-</td>
</tr>
<tr>
<td>C</td>
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<tr>
<td>D</td>
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</tr>
<tr>
<td>E</td>
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<td>45.72</td>
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<tr>
<td>F</td>
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<td>G</td>
<td>55.75</td>
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</tr>
<tr>
<td>H</td>
<td>3.8</td>
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<tr>
<td>I</td>
<td>53.90</td>
<td>54.02</td>
</tr>
<tr>
<td>J</td>
<td>2.29</td>
<td>2.54</td>
</tr>
</tbody>
</table>

FIG F15  Cover Proper

<table>
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<tbody>
<tr>
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<td>min</td>
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</tr>
<tr>
<td>D</td>
<td>12.7</td>
<td>13.5</td>
</tr>
<tr>
<td>E</td>
<td>4.8</td>
<td>5.6</td>
</tr>
<tr>
<td>F</td>
<td>13.5</td>
<td>14.3</td>
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<td>G</td>
<td>23.8</td>
<td>24.6</td>
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<tr>
<td>H</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>I</td>
<td>7.9</td>
<td>-</td>
</tr>
<tr>
<td>J</td>
<td>12.27</td>
<td>12.32</td>
</tr>
<tr>
<td>K</td>
<td>16.38</td>
<td>16.64</td>
</tr>
<tr>
<td>L</td>
<td>18.65</td>
<td>19.45</td>
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</tbody>
</table>
FIG F16 Test Cup and Lid Assembly

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<th>max</th>
<th>min</th>
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</thead>
<tbody>
<tr>
<td>A</td>
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<td>19.8</td>
<td>0.72</td>
<td>0.78</td>
</tr>
<tr>
<td>B</td>
<td>2.38</td>
<td>3.18</td>
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<td>0.125</td>
</tr>
<tr>
<td>C</td>
<td>7.6</td>
<td>8.4</td>
<td>0.30</td>
<td>0.33</td>
</tr>
<tr>
<td>D</td>
<td>2.0</td>
<td>2.8</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>E</td>
<td>0.69</td>
<td>0.79</td>
<td>0.027</td>
<td>0.031</td>
</tr>
<tr>
<td>F</td>
<td>2.0</td>
<td>2.8</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>G</td>
<td>6.4</td>
<td>10.4</td>
<td>0.25</td>
<td>0.11</td>
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<td>H</td>
<td>9.6</td>
<td>11.2</td>
<td>0.38</td>
<td>0.44</td>
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<tr>
<td>I</td>
<td>43.0</td>
<td>46.0</td>
<td>1.69</td>
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<tr>
<td>J</td>
<td>50.0</td>
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<td>-</td>
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<td>M</td>
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<td>44.4</td>
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<td>1.75</td>
</tr>
<tr>
<td>N</td>
<td>7.6</td>
<td>8.4</td>
<td>0.30</td>
<td>0.33</td>
</tr>
</tbody>
</table>
3. Cup

3.1 The cup shall be of brass, or other non-rusting metal of equivalent heat conductivity, and shall conform to the dimensional requirements in Fig F14. The flange shall be equipped with devices for locating the position of the cup in the stove. A handle attached to the flange of the cup is a desirable accessory.

4. Lid

4.1 Cover Proper - The cover shown in Fig F15 shall be of brass (Section 3), and shall have a rim projecting downward almost to the flange of the cup. The rim shall fit the outside of the cup with a clearance not exceeding 0.36 mm (0.014 inch). There shall be a locating device engaging with a corresponding device on the stove. The four openings in the cover A, B, C and D are shown in Fig F15.

4.2 Shutter - The lid shall be equipped with a brass (Section 3) shutter (Fig F16), operating on the plane of the upper surface of the cover. The shutter shall be so shaped and mounted that it rotates on the axis of the horizontal center of the lid between two stops so placed, that when in one extreme position, the openings A, B and C of the lid are completely closed, and when in the other extreme position, these openings are completely opened.

4.2.1 The mechanism operating the shutter should be the spring type and constructed so that when at rest the shutter shall exactly close the three openings. When operated to the other extreme, the three lid openings shall be exactly open and the tip of the exposure tube shall be fully depressed.

4.3 Flame Exposure Device - The flame exposure device (Fig F16) shall have a tip with an opening 0.69 to 0.79 mm (0.027 to 0.031 inch) in diam. This tip shall be made preferably of stainless steel, although it may be fabricated of other suitable metals. The flame exposure device shall be equipped with an operating mechanism which, when the shutter is in the "open" position, depresses the tip so that the center of the orifice is between the planes of the under and upper surfaces of the lid proper at a point on a radius passing thru the center of the larger opening A (Fig F15).

4.4 Pilot Flame - A pilot flame shall be provided for automatic relighting of the exposure flame. A bead 4 mm (5/32 inch) in diam may be mounted on the lid so that the size of the test flame can be regulated by comparison.

4.5 Stirring Device - The lid shall be equipped with a stirring device (Fig F13), mounted in the center of the lid and carrying two two-bladed metal propellers. A stirrer shaft may be coupled to the motor by a flexible shaft, or a suitable arrangement of pulleys.

5. Stove

5.1 Heat shall be supplied to the cup by means of a properly designed stove which is equivalent to an air bath. The stove shall consist of (1) an air bath and (2) a top plate on which the flange of the cup rests.

5.1.1 Air Bath - The air bath shall have a cylindrical interior and shall conform to the dimensional requirements in Fig F13. The air bath may be either a flame or electrically heated metal casting (Note 2), or an electric-resistance element (Note 3).

Note 2: If the heating element is a flame or electrically heated metal casting, it shall be so designed and used that the temperatures of the bottom and the walls are approx the same. The casting shall be designed so that products of combustion of the flame cannot pass up and come into contact with the cup.

Note 3: If the air bath is of the electric-resistance heated type, it shall be constructed so that all parts of the interior surface are heated uniformly.

5.1.2 Top Plate - The top plate shall be of metal, and shall be mounted with an air gap between it and the air bath. It may be attached to the air bath by means of three screws and spacing bushings. The bushings should have a thickness shown by dimension A and a diameter shown in dimension D in Fig F13.

6. Thermometers

6.1 Two standard thermometers shall be used with the Pensky-Martens Tester, as shown in Table 1.

Note 4: Whenever thermometers complying with ASTM requirements are not available, thermometers complying with the requirements for the Institute of Petroleum thermometer IP15F (or 15 C) PM-Low, or IP16G (or 16 C) PM-High, may be used, provided calibration corrections are used in temperature ranges where the IP requirements for scale accuracy are less stringent than those of ASTM.
FIG A1 Thermometer, Adapter, Ferrule, and Packing Plug

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<th></th>
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<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
</tr>
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TABLE 1  
Thermometers

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<th>ASTM</th>
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</thead>
<tbody>
<tr>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>20 to 230 F</td>
<td>9 F (20 to 230 F) or 9 C (–5 to 110 C)</td>
</tr>
<tr>
<td>200 to 700 F</td>
<td>10 F (200 to 700 F), or 10 C (90 to 370 C)</td>
</tr>
</tbody>
</table>

APPENDIX A1. Manufacturing Standardization of Thermometer and Ferrule

A1.1 The low-range thermometer, which conforms also to the specifications of the cup thermometer in the Tag Closed Tester (ASTM Method D 56, Test for Flash Point by Tag Closed Tester) and which frequently is fitted with a metal ferrule intended to fit the collar on the lid of the Tag Flash Tester, can be supplemented by an adapter (Fig A1) to be used in the larger diam collar of the Fensky-Martens apparatus. Differences in dimensions of these collars, which do not affect test results, are a source of unnecessary trouble to manufacturers and suppliers of instruments, as well as to users.

A1.2 Subcommittee 21 on Metalware Laboratory Apparatus, of Committee E-1 on Methods of Testing, has studied this problem and has established some dimensional requirements which are shown in Fig A1. Conformity to these requirements is not mandatory, but is desirable to users as well as suppliers of Fensky-Martens Testers.

Flash Radiography of High-Speed Events.
See X-Ray High-Speed Photography in Vol 2, p C17-R, under CAMERAS

Flash Reducer. In US Ordnance, any material issued separately for use with a propelling charge to reduce its muzzle flash. Differs from "flash suppressor" (qv).

Ref: Glossary of Ordn. (1959), 119-R

Flash-Reducing (or Antiflash) Agents. Ordinary smokeless propellants, burning in the chamber of a gun at the expense of its own oxygen, produce a gas mixture containing \( \text{N}_2, \text{CO}, \text{CO}_2, \text{H}_2 \) and \( \text{H}_2\text{O} \). The temp of combustion is usually so high that these gases may flash even before they leave the muzzle of the gun. This flash, however, is usually not as bright as that produced by the ignition of combustible components (such as CO and \( \text{H}_2 \)) at the instant they come in contact with oxygen of the air at the gun muzzle. This after-ignition (known as muzzle flash) takes place close to the muzzle and is visible for long distances, especially at night. The larger the gun, the greater and brighter is the flash and the more difficult it is to eliminate (Ref 2, p 130).

As an example, accdg to Davis (Ref 3), when a 12 inch gun is fired there is a large and dazzlingly bright muzzle flash, which is about 150 ft in length. The light from such a flame is reflected from the sky at night and is visible for a distance as great as 30 miles, much farther than the sound from the gun travels. The enemy, by the use of suitable range finding apparatus, may determine the position of the flash and destroy the gun by long range bombardment. Other disadvantages of a bright flash from any gun, large or small, especially in night-fighting are obvious and, consequently, elimination of flash is of prime importance.

The problem of "flash elimination" was originally investigated in France by Dautuche (Ref 1) and continued by Demougin (Ref 2), Fauveau & Le Paire (Ref 3) and Prettre (Ref 4). The subject has also been extensively investigated in the USA (Ref 5).

There are several ways in which the muzzle flash can be reduced or even eliminated:

1) By incorporating in the smokeless proplnt substances such as KCl, NaCl, K\(_2\)SO\(_4\), etc which volatilize and dissociate during the burning of the proplnt, thus lowering the overall temp of the combust gases. It has also been found by Fauveau & Le Paire (Ref 3) and Prettre (Ref 4) that these substances will lower the ignition temp of CO in the muzzle gases when it comes in contact with air (See under "Antioxidants" in Vol 1, p A471). Accdg to Davis (Ref 7, p 325), potassium hydrogen tartrate also acts as an "antioxidant", but its action differs in that it decomposes and thus absorbs some heat from the gases.
formed on deflagration of propellant, thus lowering their temps. The same author (p 323) stated that tin or other substances which may be dispersed throughout the gas formed during deflagration of propellant also act as "antioxidants" or flash reducers.

2) By incorporating in the propellant organic non-explosive substances, such as cellulose, vaseline, cellulose acetate, urea, hydrocellulose, centralites, stearic acid etc, which alter the comp of the gas mixture produced by the deflagrating propellant by appreciably increasing the number of mols of gas formed, thus lowering the temp by "dilution".

3) By incorporating in the propellant "cool explosives" such as AN, DNT, Mononitronaphthalene, Dinitr oxyylene, Guanidine nitrate, Nitroguanidine etc, which deflagrate with the production of gases which are considerably cooler than the gases from the deflagm of ordinary smokeless propellant. It should be noted that, when NG (Nitroglycerol) is replaced by NGc (Nitroglycerol) in Double-Base and Triple-Base propellants, "cooler" substances are obtained (See "Cooling Agents or Coolers" and "Cool (or Cooled) Propellants in Vol 3 of Encycl, pp C511-L to C512-L) (Double-Base and Triple-Base Propellants are described in Vol 5, pp D1536-L to D1539-L)

4) By incorporating in the propellant substances such as NaHCO₃, KHCO₃, (NH₄)₂C₂O₄, K₄Fe(CN)₆, permanganates, chromates, oxalates, tartrates etc which decompose at high temps, absorbing some of the heat of combustion, thus lowering the overall temp of the gases.

5) By incorporating in the propellant small quantities of Antiknock Compounds, described as "Antidetonating or Antiknock Compounds" in Vol 1, pp A462-R & A463-L. One of such substances, tetraethyl lead, was proposed by the French. They were supposed to eliminate flash, at least partially (Ref 2, p 139)

6) By changing the design of the gun itself, or changing the design of igniter in such a manner that the projectile takes up energy from the propellant gas more quickly and more efficiently, thus lowering the temp of the gases to a point where flash does not occur (Ref 7, p 324)

It is interesting to note that Black Powder was the original flash reducing agent. Dau triche added it in small quantities to Poudre B used in small arms and succeeded in eliminating flash completely. During WWI, the French successfully used flashless propellants in machine gun shells which contained 90% Smokeless Propellant and 10% Black Powder. For large guns they used anti-flash bags ("sachet antilueurs") filled with potassium hydrogen tartrate or argols, which are by-products of the wine industry. The Germans used in their guns "antiflash bags" ("Vorlage") filled with coarsely pulverized potassium chloride or potassium sulfate which were loaded at the base of the projectile between the projectile and the propellant charge.

Accdg to Demougin (Ref 2, p 134) the best anti flash ("antilueurs"), arranged in approx order of decreasing effectiveness, are KCI (preferably paraffined to avoid the absorption of moisture), technical KH hydrate, KH oxalate, K nitrate alone or incorporated with 20% DNT, K sulfate and Black Powder (See also under "Cooling Agents", Vol 3 pp C511-L to C512-L).

Many of the materials used for flash reduction are also used in Permissible Explosives, suggesting that the two problems may be closely related.

Following is a summary of proposed Flash-Reducing Agents, some of which have been used: K₂SO₄, KCI, KH tarttrate, powdered Sn or SnO₂, NH₄NO₃, GuN, NGs, oxalilide, hydrocellulose, starch, anthracene, Nitroaromatic Compounds, NH₄ oxalate, camphor, triacetin, nitroquinoic acid salts, acetyl laurin, dibutyl tartrate, ethyl palmitate, TN-Naphthalene, phenantherene, dicyandiamide, tricyantriamide, colophony, abietates (C₁₉H₃₉COOH) and cellulose (See also Ref 6).

Refs: 1) H. Dau triche, CR 146, 535(1908)
2) P. Demougin, MP 25, 130-9 (1932-1933)
3) J. Fauveau & ?. Le Paire, MP 25, 142 (1932-1933)
4) M. Prettre, MP 25, 160-69 (1932-1933)
5) C.G. Stone, Army Ordn 21, 20-4 (1940)
6) Thorpe 4, 521-23 (1940)
7) Davis (1943), 322-27

Addnl Refs:
A) W.O. Snelling, USP 1808613 (1931) & CA 25, 4405 (1931) (Flashless propellats obd by
incorporating in Nitrostarch one of the following substances: GuN, AN, Urea Nitrate or NGu.

B) R.G. Woodbridge, USP 1838345; 1838347 (1931) & CA 26, 1445 (1932). See also CA 27, 1177 (1933) and 30, 6946 (1936) (Proposed addn of 0.5-2% K sulfate to propiants

C) R.G. Woodbridge, USP 1838346(1931) & CA 26, 1445 (1932) (Proposed stannous phthalate as flash reducer)

D) G.C. Hale & D.R. Cameron, USP 2026531 (1936) & CA 30, 1233 (1936); also USP 2031571 (1936) & CA 30, 3650 (1936) (Flashless propiant contg NC with 10-15% TNT and 2-10% triacetin or NC with triacetin alone. The triacetin functions as a flash reducing and gelatinizing agent)

E) E. Sigg, GerP 636977 (1936) & CA 31, 3280 (1937). [Muzzle flash in firearms is reduced by placing at the base of the projectile one of the following: salts of nitric acid (such as K Dinitromethoxyquinoi nitrate, C\textsubscript{2}H\textsubscript{4}N\textsubscript{3}O\textsubscript{6}K) or highly nitratated aromatic compounds]

F) E.S. Goodyear, USP 2228309 (1941) & CA 35, 2722 (1941) (Flashless nonhygroscopic propellant: NC (N=13%) 73-79, DNT 21-24 and DPhA 0.8-1.2%)

G) T. Thomson & F.W. Whitworth, USP 2364337 (1943) & CA 37, 3938 (1943) (NC propiant contg 1-5% of an antimoyl compd free from halogens and contg a combined alkali metal, such as tartar emetic, which serves as an antiflash & antifouling ingredient)

H) G. Barsky, USP 2439291 (1948) & CA 42, 4349 (1948). See "Flashless Propellant of Barsky"


J) J.N. Pring, USP 2557663 (1951) & CA 45, 9864 (1951) (In cannon propiants with NGu, substantial improvement in ballistic prop results if its specific surface is controlled at a value in excess of 9000 sq cm/cc. Typical compn: NC (N=13.1 to 13.2%) 19, NGu (9000-22000 sq cm/cc) 55, NG 18.7 & DEDPhUrea 7.3%. The propiant can be manufd by either conventional solvent or solventless process. Where flash reduction is particularly difficult 1 to 3% of K sulfate is helpful although the amt of smoke is increased)

K) A.M. Ball, USP 2577928 (1951) & CA 46, 3764 (1952) (Flashless mortar-type smokeless propellant in sheet form, such as: NC (13.25% N) 55.0, NG 33.65. cooler-plasticizer [such as o-C\textsubscript{2}H\textsubscript{4}(CO\textsubscript{2}Et)\textsubscript{3}] 0.5, stabilizer DPhA 0.6, K nitrate (to aid ignition) 1.25% & desensitizer added methylcellulose 0.20 parts. Thickness of sheet controls ignition time)

L) J.T. Agnew, TransAmerSocMechEngs 74, 333-42 (1952) & CA 46, 4798 (1952) (Line-reversal technique in det of temp of gun flash is discussed. Monochromator is used to isolate Na, K, water-vapor radiation at 0.589, 0.77 & 0.942 microns resp. Peak temp values detd for external gaseous expls commonly known as secondary flash associated with firing a gun)

M) T. Okawa, JIndExplSocJapan 13, 247-58 (1952) & CA 49, 584 (1955) (Muzzle flashes of TNT, BkPdr, Gelatin- and Ammoni-Dynamites expelled from mortar barrels were photographed by 16-mm camera at 4500-5000 frames per second. Jetting velocities of exploded gases were 1300-2300m/sec and decreased rapidly to 300-500m/sec. Max propagation vel of TNT’s 2nd flame was 560m/sec

N) D.B. Murphy et al., PATR 2029 (1954) (High nitrogen compds as flash reducing agents)

O) B.W. Lewis & C. Boyars, USP 3097123 (1963) & CA 59, 7311 (1963) [Cool NC-base, non-C-forming propiant, such as contg NC (12.6% N) 87.0, coolant (Ba stearate) 9.0, antiflash agent (K sulfate) 2.0, bore-lubricant (Basic Pb carbonate) 1.0 & EtCentr 1.0%. Calcd flame temp 1870cal/g and no C formed. Same compn w/o K sulfate produced C at 2000°]

P) F.A. Zihlman et al., USP 3116190 (1963) & CA 60, 7864 (1964) (Propiant with flame temp 1950-2200°K; there are no C deposits and reduced barrel erosion. Compn: NC(12% N) 87.5-91.4, EtCentr 2.8-6.0, lube (Basic Pb carbonate) 3.5-4.0, K sulfate 0.3 parts with some coolant (Ba stearate))

Flash Reduction in German Projectiles. When it was required during WWII by the German High Command to have explosive flashes of Flak (AA) projectiles practically invisible in the night sky, the Krummel Fabrik AG satisfied the requirement in the following manner: The high explosive filling was completely surrounded by a 5-6mm layer (sheath) of chlorine atom containing material, such as tetra-chloro- or hexachloronaphthalene or by Amm chloride.

Refs: 1) PBRept 925 (1945), Appendix 7
2) PATR 2510 (1958), p Ger 51-R

Flash Reduction in German Propellants (Mündungsgasverrindung oder Mündungsfeuerkämperung). In order to reduce the flash produced on combustion of propellants, the Germans for many years used the salts of potassium, such as K sulfate, K nitrate, or K oxalate. The investigation conducted before WWII has shown that of the inorganic compounds the best flash reducers are the alkali salts and that flashlessness is improved on going up the series in the Periodic System. (Cs is better than Rb and Rb is better than K)

The inorganic flash reducers (such as K sulfate) were usually loaded in small bags separately from the propellant, and placed between the projectile and the propellant. These anti-flash bags, called in German “Vorlage”, consisted of two perforated discs of artificial silk or cotton cloth sewn together in the form of “doughnut” and filled with coarsely pulverized K sulfate. (Ref 1, p 324)

Another flash reducer consisted of a large bag with oxalic acid and a small bag with K oxalate.

With the incorporation during WWII of Nitroganidine (NGu) in some propellants (See Gudolpulver), it was found that NGu alone gave sufficient flashlessness without incorporating any of the usual flash reducing agents. For propellants which did not contain NGu, flashlessness could be successfully achieved by using a small bag with NGu and a small bag with K nitrate.

It should be noted that the use of inert (non-explosive and non-combustible) flash reducers such as K sulfate, nitrate, or oxalate, oxalic acid etc, is always bound to decrease the ballistic potential of the propellant and their use in large amounts should be avoided. This does not apply to NGu because this compd is not inert but is an explosive. For this reason, much larger amounts of NGu may be used, either directly incorporated in a powder, or used in a separate bag.

The following German flash reductants were examined at Picatinny Arsenal (Ref 3) during WWII:

a) K chloride; was used in 76.2mm AP weapons
b) K sulfate; was used in 7.92 Ball, 20mm APHV, 20mm Inc, 20mm HE Mauser, 20mm Solothurn, 37mm APHV, 37mm APMB, 37mm HE, 50mm HE, 75mm AP, 75mm HE and 100mm K18 weapons
c) Sodium bicarbonate; was used in some 88mm AP guns
d) Sodium sulfate; was used in some 75mm HE guns

According to Ref 4, the following compds were examined at the Döbenburg Fabrik Dynamit AG as possible flash reducers (Flammendämpfer):

Aminoguanidine bicarbonate, Amm acetate, Amm phosphate, Amm sulfate, apatite, asbestos, Ba sulfate, boron nitride, cerium oxide, cryolite, dicyandiamide, dimethyl oxamide, dimethyl urea, disodium phosphate, mercurous nitrate, methylene urea, K bicarbonate, K nitrate, K chlorate, K iodide, K metaphosphate, K perchlorate, K phosphate, K silico-fluoride, K urea oxalate, sodium ammonium sulfate, sulfur, zinc sulfate and Zn oxide

It was claimed that methylene urea reduced the flash to a far greater extent than any of the organic compounds used. It was also stated that cerium salts were much more effective than any other metallic salts investigated (Ref 4)

Abbreviations: AP Armor-piercing; HE High-explosive; HV Hyper velocity; MB Monoblock; Inc Incendiary

Refs: 1) Davis (1943), 324; 2) O.W. Stick-
3) W.R. Toulmin, PATR 1555 (1945)
4) A.A. Swanson & D.D. Sager, CIOS Rept 29/24 (1946), p 6

**Flash Signals.** See Pyrotechnic devices and Flashlight Compositions used in flash signals

**Flash Suppressor.** In US Ordnance, any material incorporated into a propellant to suppress flash. Differs from a “flash reducer” (qv) Refs: 1) Chart (1946), 51 & 164  2) Glossary of Ordn (1959), 119-R

**Flash Test for Caps.** See Vol 1, p XIX, “Optical Method for Testing Caps”

**Flash Tubes.** Device used in mortar ammunition to transmit the flash from the primer element to the middle of the propellant charge. Such an arrangement improved uniformity of ignition and reduced dispersion of fire. These tubes were formerly made from NC plastic which softened on absorbing NG from propellant causing the tube to collapse. At present the tubes are manufd from a slightly impregnated rolled paper. See Vol 4, pp D797-R to D803-L

**Flat Plate Test and Cylinder Test.** The small scale plate test is an experimental technique for evaluating the energy release from a detonating HE. It consists of a heavily confined column of HE, with a detonator & booster at one end, and a metal plate at the other end. The length of column is such that the results are independent of the detonator system. The test is run in a carefully standardized way with a constant vol of test expl; the measurement consists of determining the final plate vel by optical techniques. The plate is under acceleration for 2 to 4 μsec (Ref 1)

A much larger experiment is conducted with the flat-plate test. Pin techniques are used to measure final plate velocity. For large scale testing of highly sensitive, expensive systems, the flat plate test has advantages over end-on tests in that lens & edge effects may be eliminated without using large amts of expl. The flat plate test also tends to accentuate the importance of the lower regions of the adiabat. The plate is under acceleration for a longer period (2 to 20 μsec) compared to the small scale plate test (Ref 1)

Another test which shows considerable promise for exploring time-dependent adiabats with small amts of expl is the cylinder test. The std cylinder test geometry consists of a 1 inch diam, 12 inch long expl charged fitted into a Cu tube with a 0.1022 inch thick wall. A plane wave lens and 0.5 inch thick Comp B booster are used to initiate the test expl at one end. The radial motion of the cylinder wall is measured in a plane perpendicular to the cylinder axis 7 inches from the booster end. A streak camera records the motion, using conventional shadowgraph techniques. In addn, the deton vel of the expl is measured by placing pin switches 9 inches apart on the surface of the cylinder (Ref 2)

Some of the results obtd are as follows:
### Energy Release Tests

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Density g/cc</th>
<th>Small-Scale Plate Vel mm/μsec</th>
<th>Flat Plate Velocity mm/μsec</th>
<th>Cylinder Test Velocity mm/μsec</th>
<th>Exptl Heat of Deton, H₂O liq kcal/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetranitromethane (5 moles + Tetralin (1.5 mole)</td>
<td>1.47</td>
<td>1.16</td>
<td>1.58</td>
<td>1.43</td>
<td>1.56</td>
</tr>
<tr>
<td>Tetranitromethane (5 moles) + Tetralin &amp; Decaborane (1 mole)</td>
<td>1.47</td>
<td>1.16</td>
<td>1.62</td>
<td>1.46</td>
<td>2.31</td>
</tr>
<tr>
<td>Composition B</td>
<td>1.72</td>
<td>1.08</td>
<td>1.76</td>
<td>1.55</td>
<td>1.22</td>
</tr>
<tr>
<td>PBX-9404</td>
<td>1.83</td>
<td>1.18</td>
<td>1.96</td>
<td>1.70</td>
<td>1.39</td>
</tr>
</tbody>
</table>

The above data show that the small scale plate test does not order expls in the same manner as larger more significant hydrodynamic tests.

Some experimental cylinder test results at small and large expansions for a variety of expls are presented below:

### Cylinder Test Results

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Composition</th>
<th>Density g/cc</th>
<th>Deton Vel mm/μsec</th>
<th>Cylinder Wall Velocity mm/μsec at R=R₀=5mm</th>
<th>R=R₀=19mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMX</td>
<td></td>
<td>1.891</td>
<td>9.11</td>
<td>1.65</td>
<td>1.86</td>
</tr>
<tr>
<td>PBX 9409-03</td>
<td>HMX/NC/CEF 94/3/3</td>
<td>1.841</td>
<td>8.80</td>
<td>1.57</td>
<td>1.80</td>
</tr>
<tr>
<td>PETN</td>
<td></td>
<td>1.765</td>
<td>8.16</td>
<td>1.56</td>
<td>1.79</td>
</tr>
<tr>
<td>Octol</td>
<td>HMX/TNT 78/22</td>
<td>1.821</td>
<td>8.48</td>
<td>1.53</td>
<td>1.75</td>
</tr>
<tr>
<td>Cyclotol</td>
<td>RDX/TNT 77/23</td>
<td>1.754</td>
<td>8.25</td>
<td>1.46</td>
<td>1.70</td>
</tr>
<tr>
<td>Composition B</td>
<td>RDX/TNT 64/36</td>
<td>1.717</td>
<td>7.99</td>
<td>1.39</td>
<td>1.63</td>
</tr>
<tr>
<td>TNT</td>
<td></td>
<td>1.630</td>
<td>6.94</td>
<td>1.18</td>
<td>1.40</td>
</tr>
<tr>
<td>Nitromethane</td>
<td></td>
<td>1.143</td>
<td>6.37</td>
<td>1.01</td>
<td>1.22</td>
</tr>
</tbody>
</table>

The relative ability of these expls to deliver energy to metal has been confirmed in actual full-scale metal acceleration experiments.


Flavanone or 2,3-Dihydroxyflavone, C₁₄H₁₂O₂, and other flavonones are reduction products of flavones and have similar occurrence and uses. Nitro derivatives with up to 3 nitro groups have been reported in the literature. They would appear of no expl interest having only 11% N.

Refs: Same as under Flavone.
Flavionic Acid. Same as 2,4-Dinitro-1-naphthol-7-sulfonic Acid, which will be described under Naphthol Sulfonic Acids

Flavone or 2-Phenylchromone, $C_{15}H_{10}O_2$, and other flavones are the parents of a number of yellow natural dyes found in plants, leaves, fruits and flowers. The natural materials contain OH groups and occur uncombined or as glucosides. Nitration occurs in 2-phenyl group giving a mixture of 2', 3', and 4'-nitro flavones. If there is an OH group in the benzene ring, nitration may occur there. Compds with up to three NO$_2$ groups, but not higher, are reported in the literature.

They would appear of no expl interest having only 11% N


Flèche. Fr for Arrow

Flèchette. Fr for Small Arrow

Fléchette (US) or Aerial Dart. A small fin-stabilized missile (See "Fin Stabilization and Spin Stabilization" in this Vol), a large number of which can be loaded in an artillery canister consisting of a light sheet metal casing, designed to be fired from a rifled gun. The flechette projectile, shown here as Fig F17, was developed in the USA in the early 1960's. It has a very high length/diameter ratio. Because it will be supersonic in flight, the fins (four of them) must stand out well clear of the body to be in the Mach wave induced by the nose. To enable the maximum propelling force to be developed, a sabot (which is of plastic) was required to produce a larger cross-sectional area. Since the proplnt space is limited and must be utilized to the fullest, the sabot must be a puller, rather than the conventional pusher type associated with "amor-piercing discarded sabot" (APDS) rounds used in large-caliber tank and antitank guns. Also, since the flechette is not spun, there is no centrifugal force available to dislodge the sabot at the muzzle, as there is with APDS. This means that a mechanical cutter is required to effect the separation of the sabot from the flechette. This, in turn, adds to the complexity of the system and greatly increases the possibility of inaccuracy.

Assuming that the launch of the projectile is made without imposing initial errors on the flight path, it then will proceed along the trajectory with the unspun body stabilized only by the fins.

The aim of Major Hobart's paper (Ref 2) was to examine the parameters affecting spun and fin-stabilized flight with a view to deciding which provides the better system for a low-impulse, lightweight, hand-held military weapon of small caliber. Typical examples
would be AR 15 caliber .223 rifle and the
“Special Purpose Individual Weapon” (SPIW).
The SPIW was briefly described in Ref 1. It is
a rifle firing flechette, which is approx an
inch long and approx as thick as the lead in
a pencil

The following discussion is that of Major
Hobart, as given on pp 314 & 315 of Ref 2:

The spinning of a projectile is produced by
the engraving of the bullet envelope on the
grooves of the rifling cut into the bore of the
barrel. The rate of rotation depends on the
steepness of the rifling spiral (usually ex-
pressed as one turn in x inches; it may be
referred to, in larger guns, as one turn in x
calibers, or the helix angle may be the re-
ference parameter).

The twist is almost universally constant
in pitch, although older weapons with an in-
creasing twist may be encountered occasion-
ally. In the latter case — provided the rifling
continues to grip the envelope throughout
the bullet travel in the bore — the final angle
of twist decides the rate of rotation.

In a modern military rifle, one turn in 12
inches is a very common twist, and this enables
an immediate mental calculation of the rate
of revolution of the projectile at the muzzle
— since for every one foot the bullet travels
forward in a second, it rotates once. So, with
a muzzle velocity of 3250 ft/sec, the bullet is
spun at 3250 revolutions/sec.

For other degrees of twist, the rate of
revolution can easily be calculated. For ex-
ample, at a twist of one turn in 10 inches,
the rate is 12/10 x 3250/1 revs/sec; at one
turn in 14 inches, the rate is 12/14 x 3250
revs/sec.

The degree of twist in a modern rifle is
generally just about the minimum that will
produce stability in a bullet passing thru an
atmosphere of a density corresponding to a
temperature of zero degrees centigrade. This
is to ensure that entry into a denser medium
— i.e. the target — will produce complete in-
stability, which is a desired criterion for
wound ballistics.

When a bullet is fired at short ranges, it
is generally just stable in its flight thru the
air. When fired at long ranges, the forward
velocity is lost at a greater rate than its
angular velocity, and it becomes “overspun”.
This results in the bullet’s failing to remain
in flight with its longitudinal axis along the
trajectory; it adopts a nose-up attitude pro-
ducing an angle with the trajectory (See Fig-
ure 1). Its behavior, then, is exactly that
of a gyroscope.

If the bullet is spun clockwise by the
rifling, the wind force tending to push the
nose up induces a precession, and the nose
of the bullet is turned to the right of the
trajectory as viewed from the gun. This in
turn produces a further precession, and the
nose rises.

Thus, the effect of the overspun char-
acteristic is to cause the bullet to drift
bodily to the right, away from its original
line. If there is a strong cross wind, the
bullet will be displaced in the direction of
the air flow.

A bullet from a military .223 rifle launched
at 3250 ft/sec will lose its velocity quite
rapidly until, at 400 meters, its residual
velocity will be 1800 ft/sec and its remaining
kinetic energy (½ mv²) will be ½ 55/7000 x
1800²/g ft lbf or 2.2 x 10⁻⁶ x 5.5 x 1.8² x 10⁷;
i.e. 395 ft lbf (See Figure 3).

Since the accepted figure for the pro-
duction of an incapacitating wound on an
unprotected man is 58 ft lbf, it will be seen
that, if all this energy can be conveyed to
the target, it will be more than enough.

The bullet, on striking the target which
is denser than air, immediately becomes unstable and yields up its energy to the target.
Thus the spin bullet of the characteristics
described is perfectly adequate for unpro-
tected targets out to a range of 400 meters.

A fin-stabilized projectile must have its
center of mass well forward of its center of
pressure. This means that the point thru
which gravity can be said to act must be
well in advance of the point at which the
aerodynamic forces act. A good example of
this is a metal dart which has a brass body
of considerable density and fins placed on
a lightweight wooden boom well to the rear.

When a fin-stabilized projectile is
yawing, the wind pressure exerted at the
center of pressure will rotate the rear end of the projectile about the center of mass, until the air flow exerts equal pressures on each side of all the fins, thus placing the longitudinal axis directly into the air flow. This weather-cocking effect is most pronounced when the distance of the center of pressure behind the center of mass is large, and the magnitude of the restoring moment is at its greatest (See Figure 2).

This system works well in normal flight, but—at the moment of emerging from the muzzle—the gases following up along the bore expand, accelerate, and rush past the projectile which is, therefore, at that moment flying backward relative to the air flow. This so-called intermediate zone covers the first 6 ft or so of travel from the muzzle. The effect of this reversed air flow is to increase any initial yaw at the muzzle by a factor which may be as high as 10. Thus it is absolutely imperative that initial launch conditions be perfect so that there is no yaw.

As the missile proceeds along its trajectory—assumed to be low-angle fire—there is no tendency for it to depart therefrom, and the longitudinal axis will be restrained by aerodynamic forces to follow the trajectory.

To get the center of mass well forward in a flechette of the shape shown in Figure 2, it is obviously necessary to have a long body. Reference to the title illustration shows a typical flechette with a length of 1 inch, a diameter of 1/10 inch, and a weight of 10 grains. Due to this low mass it cannot travel far, because it loses velocity very quickly.

A side wind will cause the fin-stabilized missile to turn into the wind. Therefore wind correction, when aiming, will be the opposite of that applied for a spun projectile.

The flechette, due to its light weight, can achieve a very high muzzle velocity—of the order of 4500 ft/sec. It loses velocity quickly, but at the maximum range at which a rifle can be expected to be used in war, i.e., 400 meters—it still is travelling at about 3000 ft/sec. Its kinetic energy is then \( \frac{1}{2} \frac{10}{7000} \times 3000 \times 10^{-9} \text{ ft lb} = 2.22 \times 10^{-8} \text{ ft lb} \), which is about 3.5 times that considered necessary to produce an incapacitating wound (See Figure 3).

Due to its long, thin shape, there is a lack of rigidity, and the flechette turns into a hook on impact with the target. It becomes totally unstable and imparts its full kinetic energy to the target, producing an explosive-type wound.

For a long-range weapon, therefore, the greater mass of the spun projectile is superior to the flechette.

For ranges up to 400 meters, the target effect is much the same, but the accuracy
of the flechette depends entirely on launch conditions. If the projectile can emerge from the muzzle without yaw, its accuracy is as good as that of the bullet and its higher velocity, leading to a lower vertex height, will reduce range-finding errors and increase the chance of a hit. The shorter time of flight will reduce the lead required on a moving target.

At short ranges, the effect of a cross wind is about the same in both cases — but in opposite directions.

There would seem to be a considerable future for the flechette used in a low-impulse, lightweight military weapon, provided its launching conditions at the muzzle can ensure no initial yaw.

Flegmatizatory. Rus for Phlegmatizers (qv). Accdg to Shilling (Ref 1) and Blinov (Ref 2), substances such as oil, paraffin, vaseline, wax, etc have been used to desensitize expls and also for diminishing the erosive action of propellant gases. (See under EROSION OF GUN BARREL, in Vol 5, pp E112-R to E120-R) Refs: 1) Shilling (1946), 167 (in Rus) 2) Blinov, “Kursy Artillerii”, Vol 5 (1949), 163 3) PATR 2145 (1955), p Rus 6

Flegmatizirovannyi Cheksoghen (Phlegmatized RDX). A mixt of RDX with a small quantity of wax paraffin or cerosin pressed to a d 1.65; used as base charge of detonators Ref: Gorst (1957), 100 & NewEdn (1972), 137

Flegmatizirovannyi TEN (Phlegmatized PETN). A mixt of PETN with up to 5% wax or paraffin has been used for loading shaped charges and other shells as well as in detonators Ref: Gorst (1957), 95 & NewEdn (1972), 132

Flegmatizirovannyi Trotif (Phlegmatized TNT). A mixt of TNT 94, naphthalene 4 and DNB 2% used during WWII for loading AP shells (bronzeboyynkh so ariadaov) Ref: Gorst (1957), 98 & NewEdn (1972), 135

Flerlot Powder (1870). K chlorate 40, sugar 20 & sulfur 20% Ref: Giua, Trattato 6 (1) (1959), 392-R

Flexed TNT. The design of continuous (lined) TNT charges for Mark 29 Streamliners, used in Mark 29 Antitorpedo Device. Studies at the Explosives Research Laboratory, Brunswick, Pa, have led to the development of the “Flexed TNT” charges. The method of prep consisted in filling a reinforced rubber hose with molten TNT and subjecting the hose, while the TNT is cooling and solidifying, to a mild flexing operation. Several designs of flexing machines were described, the last of which proved to be satisfactory in rather extensive operations undertaken at the Yorktown Naval Weapons Station, Yorktown, Virginia. The properties of the Flexed TNT charges, which consisted of fine-grained material, were as follows: chge density 1.4g/cm3, length of propagation unlimited for hose as low as 1 inch diam, unaffected by moisture below 12% and insensitive to rifle bullets

Charges of diams from one to 2½ inches were successfully prep’d. They were formed in reinforced rubber hose of wall thicknesses varying from 1/16 to 1/4 inch (Ref 1)

The principle embodied in Mark 29 Anti-torpedo Device was as follows: Two explosive streamers and a third streamer contg audio pickups sensitive to vibrations from the torpedo were to be trailed by a faired (joined so that external surfaces blend smoothly) cable attached to a paravane (See Note). When a torpedo passed over or under the detector streamer, one of the explosive streamers would be fired automatically to destroy the torpedo. The 2nd streamer would then be thrown automatically into the firing circle in readiness for a 2nd attack (Ref 2)

Note: Paravane is a device, usually torpedo-shaped, for protecting a ship from moored mines. It is towed by a cable and has a device that cuts the mine cable, bringing the mine to the surface. Paravanes are always used in pairs, one towed from each bow (Ref 3)

The first expl streamer developed for the Mark 29 device by the Eastern Laboratory (EL) of the duPont Co, Gibbstown, NJ was made with Pressed TNT pellets or blocks. The hose couplings, buoyancy control (air pressure) and method of initiation (by Primacord) were the same as for the NOL Streamer in use at that time. The only apparent weakness of the duPont streamer was that the pellets were broken to some extent by handling and counter mining. The disadvantage of the pellet load was largely eliminated by the EL development of a blend of flaked and ground TNT for use in the NOL canvas sock

A series of water-compatible expls based on Pentolite was developed, the preferred type being a slurry of Pentolite, AN & water with/or wo Al powder. These slurries could be poured rapidly into hose of 1½ inches or greater diam and of length 200 ft or more. For
smaller diam hose loading was by air-pressure extrusion device (Ref 2)
1943, abstracted in OSRD 6630(1946), pp 62-3
2) Eastern Laboratory, Explosives Department, E.I. duPont de Nemours and Company, "De-
velopment of Linear Charges: Final Report on Mark 29 Device", OSRD 3781, June 1944, ab-
stracted in OSRD 6630(1946), pp 146-48
3) "The American College Dictionary", Random House, NY(1952), 880-L

Flexible Explosives. "Detasheet" explosives, consisting of PETN, RDX or HMX and elastomer
binder in cord, bar or sheet form, are described in new, updated booklet. Changes include re-
vised sections, addition of "Detasheet" D, and inclusion of federal stock numbers. Detas-
heet Flexible Explosives, Booklet A-62232, E.I. duPont, Pompton Lakes, NJ 07442. (See
also Vol 3 of Encycl, pp D99-L to D101-L)

Flex Test for Barrier Materials. A mechanical flex test to replace the US Specification MIL-
B-131B Performance Test of water vapor-proof barrier material (July 1952), which is
costly and time-consuming, was developed at Picatinny Arsenal. Three mechanical flexing
devices, each having a basically different action, were evaluated as possible substitu-
tes for the above spec test:
    a) MIL-B-131B Gelbo Tester (modified)
    b) Delaminator Tester flexing at 160°F/100% RH and under ambient conditions
    c) Point-Flex Tester
The point-flex test developed in this work was not considered an adequate substitute for the
MIL-B-131B Performance Test. This test, like the Water Vapor Transmission Rate (WVTR)
test after low-temp flexing at -20°F separates good from poor materials in the same manner
as the spec test, but does not rate barrier materials in the same order of quality.

It was recommended, however, that Specification MIL-B-131B be revised and some
features of the point-flex test and max WVTR values for barrier materials be incorporated
Ref: R.H. Evans & S. Liff, "A Flex Test for

Waterproof Barrier Materials", PATR
2302(June 1956)

FLEX-X. An adhesive-backed version of

Detasheet (See Vol 3, pp D99-L to D101-L)

Flexible Hollow Spheres. Lethal hollow
spheres which may be used to destroy enemy
targets in outer space by high velocity impact
are patented by Hershkowitz (Ref). The hollow
spheres are formed of resilient material which
is highly impregnated with metallic particles.
The spheres are flattened, partially evacuated
and sealed so that each contains a small pre-
determined vol of gas or air trapped therein
at STP. Thus, they occupy less space and a
greater number of flattened spheres can be
packed in a rocket or shell for subsequent
projection toward a selected target in outer
space. As the spheres are projected thru
space or rarefied air toward a target, the re-
late increase in pressure of the expanding
gas or air trapped in the spheres causes them
to expand outwardly to their full spherical
shape when discharged from their delivery
container for lethal impact
Ref: J. Hershkowitz, USP 3749016(July 1973)

Flintlock or Firelock. A small-arms firing
device ("gunlock") invented in Spain in the
middle of the 17th century to replace the
earlier device, known as wheel-lock (See
Ref 3, p D754-L & R). The early version of
flintlock was known as snap-hamce (See Ref 3,
p D755-L). The device was improved in
1670-1680 to such an extent that it started
to be used by all nations. In the latest model,
the flint was clamped in a spring-driven cock,
controlled by a sear (a pivoted latch) operated
by the trigger. When the cock fell under the
action of the spring, the flint struck a steel
hammer, which was hinged over the flash pan,
protected by a cover from rain or fog. The
blow uncovered the pan and produced a shower
of sparks directed into the priming powder.
The improved version of flintlock was used by
the British until about 1850 and by the
Americans as late as the end of the Civil
War. It was replaced by percussion-lock  
2) T.J. Hayes, "Elements of Ordnance", Wiley, NY (1938), 625  
D753-R to D756-L (Brief description of matchlock, wheel-lock, flintlock and percussion-lock in Section entitled "History of Development of Military Detonators, Igniters, Primers and Other Initiating Devices")

Flocculation. The formation of larger particles of a solid phase dispersed in a solution by the gathering together of smaller particles. The process whereby initial aggregates (having dimensions of a few unit cells) in a sol develop spontaneously into particles of a new stable phase is known as nucleation. When these particles grow to size sufficient to scatter visible light, they are known as colloids. Dispersions of particles of colloidal size (colloidal soins) are frequently stable, coalescence of the particles into larger aggregates settling under gravitational or centrifugal forces being prevented by their similar residual and mutually repelling charges. By changing the ionic environment in which colloidal particles exist, for example, by adding salts contg multi charged ions, the colloidal particles can be made to undergo further aggregation or flocculation. Silver chloride is a good example of a compound which can be precipitated as a flocculated colloid  

Flobert Rifle and Ammunition, known in Russia and some other countries as Monte- cristo, is briefly described in Ref 4, p D756-L. Although invented in 1840, it is still used for target practice and shooting small birds. The ammunition consists of a short metallic cartridge, cal .22, (resembling a large blasting cap), charged with a primary mixture: MF+KClO₃+Sb₂S₃, (serving as a propbnt) and a small lead bullet. The ignition of mixt is caused by the compression of the rim of the case against the breech of the barrel when it is struck by the hammer of the firing mechanism. The pressure of gas developed in the cartridge is sufficient to propel the bullet a few yards  

In order to be able to fire at longer range, the Amer inventors H. Smith & D. Wesson made the cartridges longer and placed a charge of BkPdt betw the primary mixt and bullet. The early models of Smith-Wesson revolvers had these cartridges  
The same system was adopted in larger than cal .22 weapons, including cal .41 Vetterli Repeating Rifle used in 1870's & 1880's by the Swiss army  

Rim fire weapons (such as Flobert) are replaced by center-fire weapons (See Ref 3, pp C74 & C75)  
3) Fedoroff & Sheffield, Encycl of Expls, Vol 2(1962), pp C74 & C75  

Flugel. A series of metallized expls, consisting of slurries of finely divided Al–AN or Al–AN–TNT have been manuf since 1961 at the Hercules plant in Gilbert, Minn and since 1963 in Ishpheming, Mich  
Ref: Anon, C&EN 42, 30-L, 27 April, 1964

Flotation or Froth Flotation. According to De Vaney (Ref, Perry, p 1088) flotation is a "process whereby the grains of one or more minerals, or chemical compound in a pulp or slurry, are selectively caused to rise to the surface in a cell or tank by the action of bubbles of air. The grains are caught in a froth formed on the surface of the tank and are removed with the froth, while the grains that do not rise, remain in the slurry and are drawn off the bottom of the cell or tank. Flotability is a surface phenomenon and some solids are more easily floatable (such as sulfur, sulfides of the metals, graphite) than others (such as oxides, silicates, silica).
Agents used to form a froth are pine oil, cresylic acid and the branched chain alcohols sold by duPont as B series or a mixture of these, alcohols with fuel, or pine oil, sold by the American Cyanamid Co as "AC series"

The first oil flotation plant was installed about 1914 and since then it has replaced to a certain extent the "Tabling Method" (See Note, below) developed in about 1896 by Wilfey. Tabling is still used for the treatment of material that contains only one valuable mineral of granular size and where a considerable difference exists between the effective specific gravities of the mineral constituents. Flotation, on the contrary, is best suited for treating complex ores containing several valuable minerals, those requiring fine grinding for liberation and those having small gravity differentials.

NOTE: Tabling is a concentration process whereby a separation between two or more minerals is effected by flowing a pulp across a riffled plane surface inclined sl from the horizontal, differentially shaken in the direction of the long axis and washed with an even flow of water at right angles to the direction of motion.

Dry Tabling has a shaking motion somewhat similar to that of a wet table, except that the direction of motion is inclined upward from the horizontal, and instead of water acting as the medium of distribution, a blast of air is driven thru a perforated deck.


Flo-Turn Process for Forming Shell Bodies.

Picatinny Arsenal now includes among its new precision and cam controlled machine equipment a flo-turn machine capable of machining contourd or tapered shells up to 42 inches in dia and 60 inches long. Flo-turning is basically a cold rolling process in which the displacement of metal is parallel to the centerline of the part being formed. This movement of metal is produced by action of a cam controlled & hydraulically operated roller against a blank to be formed which in turn is backed up by a mandrel.

Metal displacement in the flo-turn process differs from metal displacement in the cold rolling mill-process in that flo-turning displaces the metal in a spiral manner as work revolvs as compared to the displacement of metal in a longitudinal direction in the cold rolling process.

Flo-turning differs from spinning in that metal is displaced rather than bent into shape. The wall thickness of a spun part is basically maintained but the outside dia of the blank is reduced as it is wrapped over a mandrel. Flo-turning maintains its outside dia thruout the process and has a resultant wall thickness equal to the sine of the angle of the finished piece multiplied by the blank thickness.
The advantages of producing parts by the flo-tum process are as follows:

a) seamless parts may be produced  
b) tolerances comparable to those achieved by machining are possible  
c) surface finish is of high quality as the metal is burnished rather than cut  
d) complex contours may be flow turned  
e) metal waste is almost eliminated  
f) mechanical props of the material may be greatly improved due to extreme cold working  
g) in-process heat treatment may be eliminated by using work hardening alloys  
h) when welding preforms are used, joints are improved by plastic deformation and are less noticeable on the finished part  
i) unit cost is low due to speed of the process  
j) tooling cost is moderate allowing economical production of a relatively small number of parts and  
k) integral circumferential stiffening members may be incorporated at the ends of the parts  

A major accomplishment of the flo-tum process is the manuf of the Davy Crockett Projectile Body  


Flour. Finely ground grains of wheat, rye, corn, etc consisting of starch, gluten, etc. Besides its use as food, flour is used as combustible (carbonaceous) ingredient of expl comps, such as Gelignite, Gomm E, Dynamite II, Belgian Explosifs SGP, German Kohlen-Carbonit, etc  

Ref: Marshall 1(1917), 172, 273 & 276  
2) Davis (1943), 340-51

Flour, Cellulosic. To this belong sawdust, woodflour, woodmeal, woodpulp, etc. For example, woodmeal has been used in French expl combos, such as Dynamite-gommes and Gélatines B (potasse) and B (soude); Belgian Forcites used to be manufd at Baelen-sur- Nèthe; British Saxonite, Samsonite, Arkit No 2, Duxite, Cambite, Britanite No 2, Super-Kolax No 1 & No 2; and German Carbonit, Tutol & Kolax  

Ref: Marshall 1(1917), 372-76

Flour Tester. An apparatus invented in Sweden for approx measurement of particle size of wood pulps. It consists of various sizes of sieves and a device to feed water at a constant rate and at constant pressure of ca 2kg/sq cm. A slurry contg about 2g of woodpulp (on a dry basis) per liter of water is placed on a sieve which has the required openings. Water is admitted at constant rate & pressure and, after running from 3 to 5 mins, is then closed and the sieve removed, dried & weighed. The percent pulp retained & passed thru the sieve is determined. Repeating the operation using smaller sizes of sieves, Brissaud used this app to determine the fineness of various Nitrocelluloses and found the method to be simple & reliable  

Ref: L. Brissaud, MP 30, 201-04 (1948) (Mesure de la finesse des cotonet-poudre. Examen d'un appareil suédois "Flour Tester")

Flow of Fluids (Flow of Liquids and Gases). See under Fluid Mechanics or Dynamics


Flow Velocity in Shock. See Vol 4, p D516-R, Ref 11 and Fig 5 on p D517-L

Flow Velocity of the Detonation Products of Explosives. Formulas, based on hydrodynamic theory, were developed for the detn of the detonation products of gaseous mixtures and
condensed explosives such as TNT, PA and Tetryl.
Refs: 1) L.D. Landau & K.P. Stanyukovich, CR AcadSci(Russia) 47, No 3, 199–201 (1945)
2) Ibid, No 4, 271–4 (1945) & CA 40, 4217 (1946)

**Flex.** Fluorine/Oxygen Mixture for Atlas Rockets. A research program of the Lewis Research Center of NASA using this new propellant indicates that the pay load capacity is increased by 90% for 160km high orbits and by 65% for tasks with escape velocity. About 30% fluorine & 70% oxygen is taken as a basic mix.
Ref: Dr A. Langhans, Explosivst 12, 196 (1964)

**Fluctuating Velocity in Detonation Wave.** See Detonation Wave with Fluctuating Velocity in Vol 4, p D728-L, Ref 66, p 173, Item B

**Fluoric Explosive Initiator.** See V.P. Marchese, Singer Company Final Rept KD 72–75 (Nov 1970 to July 1972)

**Fluorics.** See Fluidics for Ordnance in this Vol

**Fluoric Safety and Arming of Selected Ammunition.** See V.P. Marchese, Singer Company Final Rept KD 72–68 (June 1971 to July 1972)

**Flugkörper (Ger).** Missile

**Flugzeugträger (Ger).** Aircraft Carrier

**Fluid Actuator.** A new actuator, called PyrAc, is a low cost fluid dispenser or fluid power supply powered by a pyrotechnic charge. It is non-fragmenting and is hermetically sealed. The device consists of two concentric tubes sealed at the end with a pyrotechnic charge in the inside of the fluted inner tube. The space between the fluted section and the outer cylinder provides the reservoir for the hydraulic fluid. When the inner tube is pressurized by the pyrotechnic, it inflates to cylindrical shape expelling the stored fluid or gas. The unique construction of the actuator permits long term storage of a sealed fluid reservoir because thermal expansion of the fluid is accomodated by flexing of the fluted portion of the inner tube. Applications are said to include fluid power supply for missiles, gas pressure for bag inflation for auto crash safety, and light gas gun propulsion.

"Fluid Ball!". Trademark of Olin Mathieson Chem Corp, Stamford, Conn 06904, for a coolant casting powder consisting of fully colloided NC having an average particle diam of 50 microns or less. Comp can include liq & solid modifiers. Used as binder component of modified double-base rocket propels.

**Fluid Explosives, Reactions Following Initiation of.** Initiation by gas compression and heat in various confinements is discussed for TNT, NG and German mining expls.

**Fluid Flow.** See under Fluid Mechanics or Dynamics and the following Refs

**Fluidic Explosive Initiator.** A new fluidic explosive initiator operates on compressed gas and utilizes acoustic resonance instead of electricity to initiate an explosive charge. Current applications are in various military
Fluidics for Ordnance. Fluidics is the general field of fluid devices and systems with their associated peripheral equipment used to perform sensing, logic, amplification and control functions. Fluidics is that area within the field of fluidics in which fluid components and systems perform sensing, logic amplification, or control functions, without the use of moving parts. The application of fluidic techniques to ordnance has been mainly in the field of fuze arming systems. More recently, attempts have been made to apply these devices to fuze design (Refs 3 & 6).

In general, fluid operated devices can be used to transfer motion with an amplified force or displacement, provide arming or functioning delays, and program events for complex devices. The field of fluid mechanics is large and complex but well covered in standard texts (Refs 1 & 2).

Present technology predicts that many of the control and sensing functions can be accomplished by fluidic systems. A typical digital interval timer is shown in block diagram form in Fig 22-1. As indicated in the figure, such a system may include a power supply, a time base oscillator, a multistage counter, a setting mechanism, a decoder to determine when the set time has elapsed, and an amplifier stage which feeds the output transducer (Ref 5).

Foremost in the manufacture and production of various units is the choice of material. It must have sufficient strength to withstand structural and hydraulic forces. Surface hardness, ease of fabrication, working temperature, and type of working fluid are also important (Ref 7).

The use of fluidic devices for timing applications in ordnance has the following advantages: 1) High reliability, 2) Large temperature range, 3) Unaffected by electromagnetic and nuclear radiation, 4) Effects of shock and vibration can be reduced to zero by initial choice of materials, 5) Number of system interfaces can be reduced, 6) Potential low cost by technological development, 7) Unaffected by corrosive liquids, 8) Miniaturization. The disadvantages are: 1) Limit of response time on switching speed, 2) Limit of signal propagation, 3) Large power con-

At stand-off distances of 330 ft. Features of the initiator are said to include safety, simplicity, reliability, long storage life and low cost. The initiator consists of two parts, a resonance tube and an excitation nozzle. In operation, gas flow is converted directly into thermal energy which is used in the initiation process. While the resonance tube theory for the generation of thermal energy is not new, its application in fluidic systems is unique. The device is 0.825 inch long, 0.250 inch in diam and weighs 0.125 ounce.

Refs: 1) EMX Engineering, Inc, 354 Newark-Pompton Turnpike, Wayne, NJ 07470
2) G. Cohn, Edit, Expls&Pyrots 7(4), (1974)

Weapons systems and for solid rocket and sounding rocket igniters. Because of its safety features (unique all-fire signal and absence of electrical path thru the unit) manufacturer also recommends it for use in commercial applications, including as a squib switch, replacement for standard electrical detonators in mining and heavy construction, as a safety valve in nuclear power plants and in aircraft and industrial applications where emergency procedures depend on electrically powered squibs which, in an actual emergency, would probably not have the required energy available.

Operating on gas pressures of approx 40 psig, the initiator will ignite primary explosives or propellants in 5 to 10 milliseconds. A predetermined time delay can also be built into the device. In testing for NASA Langley, ignitions were obtained.
surnption, 4) Need for contaminant-free supply, 5) Dependence on temperature and pressure.

In addition, before end items suitable for military application can be developed, the following design limitations must be overcome: 1) Oscillator stability, timer accuracy and reliability under such end item conditions of environment as military temperature range and spin 30000rpm (max for artillery fuzing), 2) Ruggedness, 3) Need for adequate power supply (for up to 200 secs operation), 4) Sample timer setting means increments as small as 0.1 secs.

In a typical electronic fuze timer the fundamental components are an oscillator and a binary counter. Using fluidic techniques, the oscillator consists of a proportional fluid amplifier with modified sonic feedback loops coupled to a digital fluid amplifier. Fig 8-1 (Ref 7) is a diagram of the amplifiers. The digital amplifier depends upon entrainment in which a stream of fluid flowing close to a surface tends to deflect towards that surface and under proper conditions touches and attaches to the surface. This attachment of the stream to the surface is known as the Coanda Effect. Fig 8-1(A) shows a digital amplifier and Fig 8-1(B) a proportional amplifier. A fluid oscillator made of both of these components is shown in Fig 9-2 (Ref 7). The binary counters or frequency divider of the timer.
can be built up of a number of flip-flop stages. See Fig 8-3 (Ref 7). These are the basic building blocks for an arming system. Fig 8-4 (Ref 7) shows a timer constructed of units of this type. Fig 24-49 (Ref 4) is a fluoric timer packaged for artillery fuze and Fig D a fuze armed by ram air pressure (Addnl Ref D).

FIG 8-1 Schematic of Flueric Amplifiers
(Ref 7)

FIG 8-2 Schematic of Flueric Pressure-compensated Oscillator
(Ref 7)
FIG 8-3 Schematic of Flueric Counter Stage
(Ref 7)
FIG 8–4 Flueric Timer

VOLUME: 5 CUBIC INCHES
SETTING: 2 to 200 SECONDS
0.1 SEC INCREMENTS

FIG 24–49 Flueric Timer Packaged
for Artillery Fuze
(Ref 4)
This fuze uses a fluidic power supply driven by ram air pressure; power enough to activate the arming circuit is reached only after a safe distance is traveled.

FIG D
(Addnl Ref D)

3) R.A. Shaffer, "The Application of Pure Fluids Technology to Artillery Fuzes", FrankfordArs Rept M66-20, Philadelphia, Pa (May 1965) (conf)(No classified information taken from this ref)
5) Anon, "The Application of Fluidic Devices to Ordnance Timers", JournalArtil 51, JANAF Fuze Committee (3 May 1967) AD 834083
6) C.J. Campagnolo & S.E. Gehman, "Fluidic Pressure and Temperature-Insensitive Oscillator for Timer Application", HDL, Rept TR 1381, Washington, DC (Feb 1968)

Addnl Refs: A) Anon, "Fluidic Systems
Fluidize. In general to convert to a liquid state; but in recent technology the term refers to processes in which a finely divided solid is caused to behave like a fluid by bringing it into suspension in a moving gas or liquid. The solids so treated are frequently catalysts and hence the term "fluid catalysts". In such a case the fluidized catalyst is brought into intimate contact and causes a desired reaction in the suspending liquid or gas mixture. Local overheating of the catalyst is greatly reduced, and portions of catalyst can be easily removed for regeneration without shutting down the unit. There are also non-catalytic applications in which the fluidized solid enters into direct reaction with the liquid or solid.

Ref: CondChemDict (1961), 504-L; 8th edit (1971), 394-R

Fluid Mechanics or Dynamics (Flow of Liquids and Gases) and Hydraulics.

Fluid Mechanics is, according to the definition given by Kirk and Othmer, the scientific treatment of the action of forces on fluids, with particular emphasis on fluids in motion.

To an engineer working in a chemical or explosives (or ammunition) plant, fluid mechanics is useful not only in predicting friction losses and interconversions of pressure and velocity, but also in producing analogies among the transport of momentum, heat and mass that provide a rational basis for the design of apparatus used in nitration, mixing, purification, distillation, separation, catalytic reactions etc.

Hydraulics is that branch of fluid mechanics which treats primarily the water in motion, the works and machinery for conducting or raising it, its use in driving machinery etc.

Fluid Transportation. In chemical industries, the fluids which are transported, range, according to Kirk & Othmer (Ref 7), from gases thru liquids of all viscosities to slurries and sludges.

Devices which are used for transporting fluids (liquids and gases) may be divided into pumps, ejectors, injectors, elevators, conveyors, air and gas pressure devices (such as acid eggs, air lifts, pulsed meters etc.). Pumps may be divided into piston (reciprocating), centrifugal, propeller, rotary-displacement, density, impact and momentum and turbine pumps. Pumps which are used for compressing gases are called "compressors".


Fluoro- or Fluoro-. A prefix indicating the presence of fluorine

Fluoborates or Fluoroborates. See under FLUORINE DERIVATIVES

Fluoboric (or Fluoroboric) Acid. See under FLUORINE DERIVATIVES

Fluoran and Derivatives

Fluoran or O₃-Phenol-phthalein-anhydride,

\[
\begin{align*}
\text{C}_6\text{H}_4 \text{O} & \quad \text{C}_6\text{H}_4 \text{CO} \\
\text{C}_6\text{H}_4 & \quad \text{C}_6\text{H}_4
\end{align*}
\]

mw 300.30, mp 173-175°, 180-184°, ndls (from alc); sol in nitric & sulfuric acids. Prepd by Baeyer as a by-product of the synthesis of phenolphthalein from phthalic anhydride, phenol, and sulfuric acid, but not purified sufficiently for analysis and identification until six years later. Prepd in about the same way (addn of boric acid) in 8% yield by Copisarow. Prepd by Ferrato from Grignard addn of OCH₃-phenyl Mgl to phthalic anhydride and acidolysis of the resulting 3,3-bis-(2-methoxy-phenyl)phthalid with concd HCl at 130-40° (Refs 1, 2, 3, 4, 5, 7, & 8)

\[x, x, x, x, x-	ext{Pentanitrofluorone},\]

\[\text{C}_9\text{H}_7\text{O}_3\text{SNO}_2;\ mw 525.30, N 13.33\%
\]

mp over 335°, plates (from Nitrobenzenel+alc), ndls (from acet+w). Prepd by Meyet (Ref 6) by warming fluoran in mixed nitric-sulfuric acid for one-half hour, drawing in water, filtering and recryst from NB+alc (Refs 1a & 6) Its expl props are not described

Refs: 1) Beil 19, 146, (676) & (173)
1a) Beil 19, 149 (Pentanitro) 2) A. Baeyer,

**Fluoranthene or Idryl and Derivatives**

*Fluoranthene* (Called 1,2-benzo-acenaphthylene or 1,8-o-phenylene-naphthylene in Gen), C_{16}H_{10} (Thought to be C_{16}H_{10} in early literature), mw 202.24, colorless ndls, sp gr 1.158 at 20°C, nD_2_1 1.739 at 20°C, bp 393°C, 217°C (30mm Hg), mp 109.5-110.5°C, sol in benz, chlf, eth, HAc & hot alc. A tetracyclic fused ring aromatic hydrocarbon, this material is found in some coal tars. It forms definite complexes with many polynitro aromatics (Refs 1 to 6) Refs: 1) Beil 5, 685, (340, 344), [609] & [2276] 2) J. vonBraun & E. Anton, Ber 62B, 145 (1929) & CA 23, 2713 (1939) 3) T. Sinomiya, BullChemSocJapan 15, 259-70 (1940) & CA 34, 7900 (1940) (Complexes with TNB, TNT, TeNB, etc) 4) M. Orchin & E.O. Woolfolk, JACS 68, 1727-9 (1946) & CA 40, 7182 (1946) (Complex with Trinitrofluorenone) 5) S.H. Tucker & M. Whalley, ChemRevs 50, 483-538 (1952) & CA 46, 8079 (1952) (The chemistry of fluoranthene, 186 refs) 6) CondChemDict (1961), 504-R; (1971), 394-R

*Mononitrofluoranthenes, C_{16}H_{8}NO_2, mw 247.24, N 5.67%*


*Dinitrofluoranthenes, C_{16}H_{8}N_2O_4, mw 292.24, N 9.59%*


*Trinitrofluoranthene, C_{16}H_8N_3O_4; mw 337.24, N 12.46%.* The earliest ref (2) to this compd describes it as being yel ndls with a mp >300°C. In Ref 3 presumably a different isomer is reported as having a mp of 300°C. Both were made by nitrating the parent compd Refs: 1) Beil 5, 686 2) F. Rittig & F. Gebhard, Ann 193, 147 (1878) 3) M.I. Shenbor & N.A. Polezhaev, KhimTekhnol 12, 111-15 (1969) & CA 72, 21534 (1970)

*Tetranitrofluoranthene, C_{16}H_8N_4O_8; mw 382.24, N 14.66%.* In Ref 2 one isomer is reported as having mp >300°C, and another as mp 188-90°C; sol in acet. Both were prepd by nitrating the parent compd at RT. Their expl props are not described in CA Refs: 1) Beil, not found 2) M.I. Shenbor & N.A. Polezhaev, KhimTekhnol 12, 111-15 (1969) & CA 72, 21534 (1970)

*Pentanitrofluoranthene, C_{16}H_8N_5O10; mw 427.24, N 16.39%.* Crysts, mp 299-302°C Prepd by nitrating the parent compd at RT. Its expl props are not described in CA Refs: 1) Beil, not found 2) M.I. Shenbor & N.A. Polezhaev, KhimTekhnol 12, 111-15 (1969) & CA 72, 21634 (1970)

"**Fluorel**" Brand 2141 Elastometer of Minnesota Mining and Mfg Co, St Paul, Minn 55119 is a fully saturated fluorinated polymer contg more than 60% F by wt and is non-flammable. Lt colored gum, sp gr 1.85, shore "A" hard-
ness 40, embrittlement temp -50°F, stable in storage and very resistant to strong bases, fuming nitric, fuming sulfuric, acetic and hydrochloric acids; sol in esters and ketones. Outstanding performance in hydraulic fluids and synthetic lubricants at elevated temperatures. Rated for continuous service at +400°F, but can withstand +600°F at limited service. Used in gaskets, hoses, wire & fabric coatings, diaphragms, fuel cells, sealants, etc.

Ref: CondChemDict (1961), 504-R; (1971), 395-L

4-Azidofluorene, C₆H₄(CH₂)₂C₆H₃N₃; mw 207.24, N 20.29%; crystals, mp 78-81°. Prepd by treating 4-aminofluorene in alc with dil sulfuric acid. Its expl props are not described in CA.
Ref: 1) Beil, not found 2) P.A.S. Smith et al, JOC 23, 526 (1958) & CA 52, 17230 (1958)

9-Azidofluorene, C₆H₄(CH(N₃)₂)C₆H₄; mw 207.24, N 20.29%; crystals, mp 43-44°. First prepd by treating 9-bromo-9-trimethylsilylfluorene with sodium azide in hot methanol, more recently by treating 9-bromofluorene itself under the same conditions. Its expl props are not described in CA.

9-Diazofluorene, C₆H₄(C₆N₂)C₆H₄; mw 192.22, N 14.58%; red ndls, mp 94-5° (dec at 159-60°), sol in alc, benz & eth. Prepd by treating fluorene-9-hydrazone with yel mercuric oxide in benz. Its expl props are not described in CA.
Ref: 1) Beil 7, (252), (408) & (2337) 2) H. Staudinger & O. Kupfer, Ber 44, 2207 (1911)

9,9-Diazodiﬂuorene, C₆H₄₂C₆H₄; mw 248.25, N 33.87%. Prepd by treating a 9,9-dihaloﬂuorene with sodium azide in acetonitrile below 0°, but not isolated in the pure state. Its expl props are not described in CA.
Ref: 1) Beil, not found 2) L. Barash et al, JACS 89, 3932-32 (1967) & CA 67, 81676 (1967)
9-Diazo-\text{x},\text{-}dinitrofluorene,
\[ \text{O}_2\text{NC}_6\text{H}_3\text{-CN}_2\text{C}_6\text{H}_3\text{-NO}_2 \text{; mw 282.22, N} 
19.86\% \text{. Three isomers were prep'd from the corresponding 9-hydrazone combs by treatment with silver oxide in refluxing tetrahydrofuran (isomer, mp of hydrazone, mp of diazo, color/form of diazo: 2.4\text{a}, 255-56^\circ \text{dec,} 192-92.5^\circ \text{dec, red-om ndls, 2.5\text{-}}, 264-66^\circ \text{dec,} 208^\circ \text{dec, orn cryst; 2.7, 275-78^\circ \text{dec}} \text{ (crude), 196-99^\circ \text{dec (crude), or crysts. Their expl props are not described in CA} } 
\text{Refs: 1) } \text{Beil, not found} \text{ 2) } \text{F.F. Guxik & A.K. Colter, CanJChem 43(5), 1441-47 (1965) & CA 63, 450 (1965) } 
\]

9-Diazo-2,4,7-trinitrofluorene,
\[ \text{O}_2\text{NC}_6\text{H}_3\text{-CN}_2\text{C}_6\text{H}_3\text{(NO}_2\text{)}_2 \text{; mw 327.22, N} 
21.41\% \text{; orn ndls, mp 204-05^\circ \text{dec. Prep'd from the corresponding hydrazone (mp 250-02^\circ \text{by oxidation with silver oxide. Its expl props are not described in CA} } 
\text{Refs: 1) } \text{Beil, not found} \text{ 2) } A.K. \text{Colter & S.S. Wang, JOC 27, 1517-20 (1962) & CA 57, 2157 (1962) } 
\]

9-Nitratofluorene, \[ \text{C}_6\text{H}_4\text{-CH(ONO}_2\text{)}\text{CN}_2\text{H}_4 \text{; mw 227.22, N} 6.17\% \text{; crysts, mp 89^\circ \text{. Prep'd by treating 9-bromofluorene with silver nitrate in acetonitrile. Its expl props are not described in CA} } 
\text{Refs: 1) } \text{Beil, not found} \text{ 2) } C. \text{Eaborn & R.A. Shaw, JCS 1955, 1420-25 & CA 50, 11300 (1956) } 
\]

Mononitrofluorenes, \[ \text{C}_1\text{H}_9\text{N}_2\text{O}_2 \text{; mw 211.22, N} 6.63\% \text{.} 
1-Nitro-, crysts, mp 104-06^\circ \text{(Ref 1) } 
2-Nitro-, ndls, mp 156^\circ \text{(Ref 2) } 
3-Nitro-, yel ndls, mp 105^\circ \text{(Ref 3) } 
4-Nitro-, yel ndls, mp 72-5^\circ \text{(Ref 4) } 
9-Nitro-, plts, mp 181-82^\circ \text{dec} \text{[Ref 5] } 
\text{Refs: 1) } Y. \text{Yost, J MedChem 12, 961 (1969) & CA 71, 112683 (1969) } 
\text{ 2) } \text{Beil 5, 685 & [535] & Y. \text{Yost (Same as Ref 1) } 
\text{ 3) Same as Ref 1 } 
\text{ 4) Same as Ref 1 } 
\text{ 5) C.D.} \text{ Nenitescu & D.A. Isaccescu, Ber 63, 2489 (1930) & CA 25, 925 (1931) } 
\]

Dinitrofluorenes, \[ \text{C}_1\text{H}_8\text{N}_2\text{O}_4 \text{; mw 256.22, N} 10.93\% \text{.} 
2,5-Dinitro-, yel ndls, mp 209^\circ \text{(Ref 1) } 
2,7-Dinitro-, col crystals, mp 333-34^\circ \text{(310^\circ )} \text{ (Ref 2) } 
2,9-Dinitro-, crystals, mp 136-37^\circ \text{(Ref 3) } 
9,9-Dinitro-, ndls, mp 130-131.5^\circ \text{dec(Ref 4) } 
\text{Trinitrofluorenes, C}_1\text{H}_9\text{N}_3\text{O}_6 \text{ are not found in the literature} 
\]

Fluorenone and Derivatives

Fluorenone (Fluorenon, 9-Oxo-fluorene, Diphenylenketon in Ger), \[ \text{C}_6\text{H}_5\text{CO.C}_6\text{H}_4 \text{; mw 180.21, yel crysts (alc), sp gr 1.130 at 99.4/4^\circ , mp 85-6^\circ \text{, bp 341.5^\circ , n D 1.6369 at 99.4^\circ \text{ solubility in g/100g at 23^\circ \text{; 7.5 in 95% alc, 19 in CCl}_4, 31 in eth, 68 in benz. First prep'd by oxidizing fluorene in hot acetic acid with sodium dichromate. Forms a 1:1 complex with nitric acid at 0^\circ , om-red ndls, mp 63-4^\circ \text{; also forms a 1:1 complex with HClO}_4. \text{Forms a 2:1 complex with TNB, mp ca 79^\circ \text{ Refs: 1) } \text{Beil 7, 465, (250), [405]} & [1230] \text{ 2) } \text{C. Graebe & A.S. Rateanu, Ann 279, 258 (1894) } 
\]

2-Azidofluorenone, \[ \text{C}_6\text{H}_4\text{CO.C}_6\text{H}_8\text{N}_3 \text{; mw 221.22, N} 19.00\% \text{; yel plates, mp 117^\circ (expt over 117^\circ ). Prep'd by treating fluorenone-2-diazonium chloride with sodium azide in water Refs: 1) } \text{Beil 7, [410] \text{ 2) A. Korczynski, BullChemSocFr [4] 35, 1191-92 (1924) } 
\]

4-Azidofluorenone, \[ \text{C}_6\text{H}_4\text{CO.C}_6\text{H}_8\text{N}_3 \text{; mw 221.22, N} 19.00\% \text{; crystalls, mp 118.5-120^\circ \text{. Prep'd by treating 4-aminofluorenone, with aq alc sulfurr acid. Its expl props are not described in CA} } 
\]
2,7-Diazidofluorenone, N₂C₆H₅.CO.C₆H₅N₆; mw 262.23, N 32.06%. Mentioned in a patent disclosure application as a possible photographic sensitizer. Its expl props are not described in CA
Refs: 1) Beil, not found 2) P.A.S. Smith et al., JOC 23, 526 (1958) & CA 52, 17230 (1958)

Mononitrofluorenone, C₁₃H₁₃NO₇, mw 225.21, N 6.22%;
1-Nitro-, yel crs, mp 191°C (Ref 1)
2-Nitro-, yel crs, mp 222–23°C (Ref 2)
3-Nitro-, crs, mp 239–40°C (Ref 3)
4-Nitro-, yel ndls, mp 174–175.5°C (Ref 4)

Dinitrofluorenone, C₁₃H₆N₂O₄, mw 270.21, N 10.37%;
1,8-Dinitro-, crs (Ref 1)
2,4-Dinitro-, yel ndls, mp 197°C (Ref 2)
2,5-Dinitro-, yel ndls, mp 241°C (Ref 3)
2,6-Dinitro-, yel ndls, mp 236–37°C (Ref 4)
2,7-Dinitro-, yel ndls, mp 292°C (Ref 5)
3,6-Dinitro-, ye, lfts, mp 344–45°C (Ref 6)
4,5-Dinitro-, ornd ndls, mp 273.5°C (Ref 7)
x,x-Dinitro-, yel ndls, mp 220°C (Ref 8)

2,3,7-Trinitrofluorenone,
O₂NC₆H₅.CO.C₆H₅(NO₂)₂; mw 315.21, N 13.33%. First reported in Ref 2, later shown to be the 2,4,7- isomer. Not otherwise found in Beil or CA

2,4,7-Trinitrofluorenone,
O₂NC₆H₅.CO.C₆H₅(NO₂)₃; mw 315.21, N 13.33%; yel ndls, mp 180–81°C (176°C); sol in acet, benz & chl; sl sol in alc, edh & HAc. Prepd by hot nitration of fluorenone or 2,7-dinitrofluorenone with mixed acid. Originally thought to be the 2,3,7-. Has some use as a complexing agent for derivatizing aromatic compds

2,3,6,7-Tetranitrofluorenone. Reported to have been prepd in Ref 2, later (Ref 3) shown to be the 2,4,5,7- isomer. Ref 4 mentions it as a reactant, but gives no prep or props

2,4,5,7-Tetranitrofluorenone,
(O₂N)₂C₆H₅.CO.C₆H₅(NO₂)₂; mw 360.20, N 15.56%; yel ndls (alc) or plates (HAc) with ½ or 1 HAc of crs, mp 253°C (HAc is lost at 120°C); sl sol in HAc. Prepd by hot mixed acid nitration of fluorenone. Originally thought to be the 2,3,6,7- isomer. Later shown to be the 2,4,5,7- isomer by prep by hot mixed acid nitration of either the 4,5-dinitro- or the 2,4,7-trinitrofluorenone (Ref 3). Has some use as a complexing agent for derivatizing aromatic compds. Its expl props are not described

Fluorenone Peroxide and Related Compounds.
In 1940 Wittig and Pieper reported the prepn of fluorenone (peroxide, C₆H₅.CO₂₂₇C₆H₅,

---

**F 123**
by reacting fluorenone (FL) in ethereal 
H$_2$O$_2$/P$_2$O$_5$; it was described as stable yel
crysts, mp 108–08.5$^\circ$ (dec over 115$^\circ$), being
sol in methanol, diff sol in benz. In 1949
Criegee et al showed by more exact analysis and
various transformations that this compd
was actually a bis/fluorenone complex of 9,9-
bis(hydroperoxy)fluorene,
\[
\text{C}_9\text{H}_8\text{O}_4\text{H}_2\text{C}_8\text{H}_4\bullet 2\text{FL}, \text{mw} 590.64(\Lambda).
\]
By heating (A) at 85–90$^\circ$ in vacuo, they ob-
tained another complex (B),
\[
\text{C}_9\text{H}_8\text{O}_4\text{H}_2\text{C}_8\text{H}_4\text{H}_2\text{C}_8\text{H}_4\bullet \text{FL}, \text{mw} 606.64;
\]
yel crysts, mp 134–35$^\circ$, explodes in a flame.
They converted (B) by treating it with Pb(Ac)$_4$
in HAc to fluorene-9 9-bisperoxide,
\[
\text{C}_9\text{H}_8\text{O}_4\text{H}_2\text{C}_8\text{H}_4\text{H}_2\text{C}_8\text{H}_4\text{H}_2, \text{mw} 392.42; \text{yel prisms},
\]
mp 203$^\circ$ (dec; explodes weakly on confined
heating). Treatment of (A) with C$_6$H$_5$COCl in
pyridine at 0$^\circ$ gave 9,9-bis(benzoylperoxy)-
fluorene, mw 438.44, colorless rhomb prisms,
mp 106$^\circ$, explodes over 106$^\circ$; with
p-O$_2$NC$_6$H$_4$COCl, 9,9-bis(p-nitrobenzoylperoxy)-
fluorene, mw 528.44; yel crysts, mp 149–50$^\circ$
(sl impure), explodes over 150$^\circ$, insol in all
usual organics. The same treatment of (B)
gave 9,9'-benzoylperoxy-9,9'-fluorene peroxide,
\[
\text{mw} 634.65, \text{colorless cryst, mp} 135^\circ (\text{deton9})
\]
Ref(s): 1) Beil 19, 222 2) Hackth's Dict (1944);
547-R 3) CondChemDict (1961), 505-L;
8th ed (1971), 395-L

**Fluorescinates of aluminum, copper and mercury were proposed as fuels in smoke generating compns**

Ref: J. DeMent, USP 2995526 (1961)

**Fluorescence, Luminescence and Phosphores-
cence.**

Fluorescence is the property of certain sub-
stances (solids, liquids or gases) to radiate
when illuminated, an unpolarized light of a
different, usually greater, wavelength. It is
due to the return of the electrons displaced
by the exciting radiation to a more stable
position. The substances having this property
are known as phosphors, the term usually being
restricted to those solids that absorb UV and
emit visible light. In usual fluorescent light-
ing, the tube contains mercury vapor and argon,
and the inside of the walls are coated with the
fluorescent substance. The passage of an electric current thru the Hg-Ar mixt pro-
duces invisible UV light which is absorbed
by the phosphor (coating on the wall) and re-
emitted as visible light. The whole process
occurs at a relatively low temperature (hence
called a "cold light" process). Besides its
use for lighting, fluorescence is used to
identify and analyze certain minerals and also
some org derivatives

Fluorescence differs from phosphores-
cence (See below) where the luminescence
(See below) continues, even after illumination
has ceased

Luminescence is the emission of light at RT
under the influence of various physical agents:
as mechanical(tribo-), electrical(electro-),
radiant( photo-), , or chemical (chemo-) means. The exciting source
also may consist of moving charged particles,
such as alpha-, beta-, or gamma-. Certain
substances luminesce on crystallization, as,
for example, on crysm of arsenous acid from HCl-soln. Luminescence produced during decay of wood is attributed to very slow chemical process and luminescence produced by living organisms is attributed to biological process (bioluminescence). If these processes are continuous, they belong to phosphorescence.

*Phosphorescence* is fluorescence that continues for more than a very short time (10^-8 seconds) after exciting radiation is stopped. As an example, may be cited the faint green glow due to oxidation of white phosphorus on its exposure to air. Also luminosity produced by organisms, such as glow-worms, deep-sea fishes and fireflies. Some mushrooms glow in the dark during their decaying


### Fluorescence Spectroscopy and Test

*Fluorescence Spectroscopy* is the branch of visible spectroscopy dealing with fluorescence.

In conducting a test, the object to be studied (such as an inorg or organic specimen) is shielded from extraneous light and is then illuminated with an ultraviolet lamp (such as a quartz mercury lamp), covered with a filter to remove visible radiation. If the sample glows (fluoresces), the spectrum of this glow is studied by spectroscopy and this permits the establishment of the identity of the sample.


### Fluorescein or Resorcinol Phthalein, C20H14O5:

**MW**: 334.32, colorless ndls (from AcOH), mp (for solvent-free) 253-54°C; insol in w; sol in alc, eth, AcOH & alkalis. Can be prepd by reduction of fluorescein or by heating p ethalic anhydride & resorcinol. Used as a reagent and in medicine; also as a dye (Reffs 1, 2, 3 & 4)


### Fluorescent Screen

A glass plate covered with a fluorescent substance, such as tung-state or platinoxyanide. Used for making visible those rays which are normally invisible to the eye.

*Reff*: Hack h's Dict (1944), 348-R

### Fluoric Acid

It could be applied to HFO₃ if it existed, but now it is sometimes erroneously used for hydrofluoric acid, HF.

### Fluoride

A salt of hydrofluoric acid containg the monovalent F-radical. The term acid fluoride refers to a salt of the type MHF₂.

*Reff*: Hack h's Dict (1944), 348-L

### Fluorides

See under FLUORINE DERIVATIVES

### Fluorinated Ethylene-propylene Resin (FEPR)

A copolymer of tetrafluoroethylene, F₂C:CF₃ and hexafluoropropylene, F₃C:CF:CF₂, which can be melt processed in conventional molding and extrusion equipment for use as wire insulation, cable jacketing, shaped objects, gaskets, seals, etc. Stands temps up to 200°C and is tough at low temps.


### Fluorinated Paraffin

A paraffin oil or wax which has been fluorinated (part of the hydrogen replaced with fluorine) usually by substitution of F in a chlorinated paraffin. Used as inert lubricant and sealant; also as heat transfer medium.

*Reff*: CondChemDict (1961), 505-R
Fluorinated Polymeric Peroxides. 1,1,4,4-Tetrafluoroethylene is shaken with O under pressure at RT to produce polymeric peroxides containing the structures [CF₃ CH:CHCF₂OO] and [CH(CH₂ CF₃)CF₂OO]. The amount of O is not specified, and the polymers may be varied over wide limits. The polymers are white solids, sold in Me₂CO, which liberate iodine from KI in aqueous Me₂CO and explode at 122°C. They are useful in rocket propellants.


Fluorinating Agent. A compound used to introduce fluorine into some other compound. The higher fluorides of cobalt (CoF₃), manganese (MnF₄), silver (AgF₂) and of chlorine and bromine are used for this purpose. The usual procedure involves replacement of chlorine. Thus, Cl₂ is treated with fluorinating agent to produce CCl₃F₂ or similar compounds.

See individual fluorine inorganic compounds in Ref 2 for their uses & properties.


FLUORINE AND DERIVATIVES

FLUORINE, F₂, mw 38.00; pale-gm, poisonous gas; extremely reactive. Was discovered in 1771 by C.W. Scheele (1742–1786) in fluorite and cryolite and isolated in 1886 by H. Moissan (1852–1907). The density of gas 1.695 (Air 1.0); sp gr of liquid at –188°C 1.108; fp –219.6°C; bp –188.1°C at 760mm; decomp by w; corrosive and reacts vigorously with most oxidizable substances at RT, frequently with ignition. Forms fluorides with most elements, except the inert gases. Occurs widely distributed to the extent 0.03% of the earth crust. The chief minerals are fluorapatite, cryolite and fluorspar.

Can be obtd by electrolysis of molten anhydrous hydrofluoric acid-potassium fluoride melts with special Cu-bearing carbon anodes, steel cathodes, containers and monel screens. Available in special steel cylinders, both as a liquid and as compressed gas.

Used as an oxidizer in rocket fuels, production of metallic and other fluorides and fluoro compounds, listed here separately.


Add Refs:
A) L.R. Brantley, Pacific Rockets 1948(Summer-Fall), pp 11–16 & CA 44, 5594 (1950) (Elemental fluorine as oxidizer in rocket engines; various aspects)
B) R.H. Lafferty, Jr et al, C&EN 26, 3336–37 (1948) & CA 43, 406 (1949) (Explosibility produced by liquid fluorine brought in contact with organic materials. For example, when neoprene was dipped into liq F at liquid N temp, a sl expln and combustion took place, whereas cotton gave an immediate violent expln with white flame)
C) G.C. Fonger et al, JACS 73, 145–49 (1951) & CA 45, 7034 (1951) (A compd of formula C₄HF₂N₅O₃ is described. It was in the form of orn-red crysts which violently exploded on impact but did not melt below 359°C. Its isomer, also explosive, melted at 119.3–120°C with decomp)
D) G.A.W. Boehm, Fortuna, Dec 1957, pp 170–72 (Fluorine is the best oxidizer after ozone; one of the most corrosive substances known. Specific impulse of F with hydrogen is 374. Less energetic but less cantankerous oxidizers are oxygen difluoride (OF₂) and tri-oxygen difluoride (O₃F₂)
E) V.I. Sichel & H.J. Matsuguma, "Investigation of Synthetic Methods for Preparing the
FLUORINE DERIVATIVES
(Fluorides and Fluorocompounds)

Their principal parent compound is Hydro-fluoric (or Phthoric) Acid Gas. (Hydrogen Fluoride), HF, mw 20.01; colorless, very poisonous gas, density 0.713 (Air=1.0), sp gr of liquid 0.998 at +13.6°, fr p –83°, bp +19.4°; sol in w or alc. Can be prepd by distilling from a mixture of Ca fluoride (fluorspar) and sulfuric acid. Used as an additive in liquid rocket propellants and in refining of uranium. Also as fluorinating agent in org and inorg reaction; prepn of Al fluoride, other fluorides, fluoroborates, fluorocarbonates, fluorocarbons and fluorosilicates.

Its aqueous soln is colorless, fuming, corrosive acid, which attacks glass and Si-contg materials. Available in commerce in strengths up to 70%. Prepd by absorbing HF gas in w. Used for polishing, etching and frosting of glass; pickling and electro-polishing of metals; purification of filter paper and graphite; dissolution of ores, etc.


(Hydrogen fluoride, anhydrous); (1971), 454-L (Hydrofluoric Acid); 455-R (Hydrogen fluoride, anhydrous)

Aluminum Fluoride Anhydrous, AlF₃, mw 83.93; wh crystals, sp gr 2.882 at 25°; mp – sublimes at about 1260° w/o melting; sl sol in w; sol in acids or alkalis; insol in most org solvents. Prepd by dissolving alumina trihydrate in aq HF, followed by crystn and calcination to remove water. Used in glass industry for manuf of porcelain ware (Reps 1 & 2)

Aluminum Fluoride Hydrate, AlF₃·3H₂O; mw 147.03; wh crystn pdr; mp – loosing 3H₂O at 250°; sl sol in w. Prepd by action of aq HF on alumina trihydrate, followed by crystn. Used for prepn of wh enamel

Aluminum Fluosilicate or Aluminum Silico-fluoride, Al₂(SiF₆)₃; mw 480.83; wh pdr; sl sol in cold w; sol in hot w. Can be prepd by treating alumina trihydrate with fluosilicic acid. Used for prepn of artificial gems, enamels & glass

Ammonium Fluoride or Malt Salt, NH₄F, mw 37.04, wh poisonous crystals; sp gr 1.31, mp – decomp by heat w/o melting; sol in cold w. Prepd by interaction of Amm and hydroxide with HF, followed by crystn. Used in glass etching, textile mordant, wood preservation and in analytical chemistry (Reps 1 & 2)

Ammonium Fluosilicate (Cryptohalite), (NH₄)₂SiF₆; mw 178.17; wh crystn pdr; sp gr 2.01, mp – sublimes; sol in alc & w. Can be prepd by interaction of Amm hydroxide with fluosilicic acid, followed by crystn. Used for glass etching, casting of light metals and electroplating

Azido Fluoride. See Fluorine Azide in Vol 1, p A536-L

Barium Fluoride, BaF₂, mw 175.36; colorless, very poisonous crts; sp gr 4.826, mp 1280°, bp 2260°; sl sol in w; sol in alc. Can be prepd by the interaction of Ba sulfate and HF, followed by crystn. Used in embalming and manuf of enamels; its single crts are used for spectroscopy (Reps 1 & 2)
Barium Fluorosilicate or Barium Silicofluoride, BaSiF₆, mw 279.45, white crystal powder, sp gr 4.279 at 15°; nearly insol in w; insol in alc; sl sol in HCl. Can be prepd by treating Ba carbonate with fluosilicic acid. Used as an insecticide.


Benzotrifluoride or Trifluoromethylbenzene (Toluene Trifluoride), C₉H₅CF₃, mw 146.11, colorless, flammable liquid, with a pungent odor, sp gr 1.1812 (25°/4), fr p 291°, bp 102.1° (760mm), nD 1.4146 at 20°, fl p 54°F (closed cup); decomps by w. miscible with alc, eth, acetone, benzene & CCl₄. Can be prepd by heating benzotrichloride with SBF₃ and by other methods (Ref 1). Used as a solvent, as a dielectric fluid, a vulcanizing agent and an insecticide.


Beryllium (Glycinium) Fluoride, BeF₂, mw 47.01, colorless, poisonous powder, sp gr 2.01 at 15°, mp 800°, bp 1460°; sol in w; sol in alc, acids and alkalis. Can be prepd by thermal decomp (at 900–950°) of ammonium beryllium fluoride. Used in production of beryllium metal by reduction with Mg metal.


Beryllium-Potassium Fluoride (Potassium-Beryllium Fluoride), BeF₂·KF; mw 163.21, colorless, poisonous crystals, sp gr ?; mp ?; sl sol in w; insol in alc. Can be prepd by mixing aqueous solns of KF & beryllium fluoride (Ref 1).


Beryllium-Sodium Fluoride (Sodium Beryllium Fluoride), BeF₂·2NaF; mw 131.00; white or grayish poisonous crystal powder; mp about 350°; bp decomps; sl sol in w; insol in alc. Can be prepd by heating an aqueous soln of NaF₂ & beryllium fluoride (Ref 1). Used for prepn of pure Be metal.


Boron Fluoride or Boron Trifluoride, BF₃, mw 57.82; colorless gas, density 2.3 (Air = 1.0), fr p 126.8°, bp -101°; sol cold w; decomps in hot w; decomps in alc. Can be prepd from BF₃·H₂O or anhyd HF or by combination of elements. Used as catalyst in org synthesis and in instruments for measuring neutron intensity.

It easily forms double compds, such as boron trifluoride etherate. Another compd, boron trifluoride-monoethyamine, BF₃·C₂H₅NH₂ is wh to pale tan flakes, melting at 88–90°. It released BF₃ above 110° and is used for elevated temp cure of epoxy resins.


Boron-Potassium Fluoride. See Fluoborate (Fluoroborate) of Potassium.

Boron-Sodium Fluoride. See Fluoborate (Fluoroborate) of Sodium.

Bromine Pentfluoride, BrF₅, mw 174.02, colorless, corrosive liq; sp gr 2.466 at 25°, mp 8.8°, bp 40.5°, vapor press 7psia at 70°F; decomps by w. Can be prepd by reaction of F₂ & KBr in the cold or by heating F₂ & ZnBr₂ (Ref 1). Used as oxidizer in liq rocket propiants.


Bromine Trifluoride or Fluorine Bromide, BrF₃, mw 136.92, colorless to yel corrosive liq; sp gr 2.803 at 24°, mp 3°, bp 135°, vapor press 15psia at 70°F; decomps violently by w and alkalis. Can be prepd by heating BrF₅ & fluorine at 200° (Ref 1). Used as fluorinating agent & electrolytic solv.

Bromodifluoroethane or difluorobromoethane, \( F_2\text{HC.CH}_2\text{Br} \), mw 144.96; colorless liq, sp gr 1.817 at 20\(^\circ\)F, fr p -74.9\(^\circ\), bp 57.3\(^\circ\); v sl sol in w, miscible with alc & eth. Can be prep'd by reaction of difluoroethyl alcohol, phosphorous & bromine.
Refs: 1) Beil 1, 89, (127), [61], [178] & <154> 2) CondChemDict (1961), not listed

Bromotrifluoroethylene (BFE) or Trifluoro-
monobromoethylene, \( \text{BrFC.CF}_2 \), mw 160.94.
The name is used both for the monomer and polymers made from it. The polymers are usually clear oils at RT and non-cracking solids at -65\(^\circ\)F(-54\(^\circ\)). The typical fluoro-
carbons are chemically inert, thermally stable, and nonflammable. The monomer can be prep'd similarly to CFE from tribromotrifluoroethane and zinc. BFE polymers are used as flotation fluids for grous and accelerators used in inertial guidance systems. Can also be used as CFE (chlorotrifluoroethylene) poly-
mers, but are more expensive.

Bromotrifluoromethane or Trifluoromono-
bromomethane ("Freon 13B1" or "F-13B1"), \( \text{BrCF}_3 \), mw 148.93; colorless gas, fr p -175\(^\circ\), bp -58\(^\circ\)(760mm); nonflammable. Can be prep'd by heating trifluoromethane & Bt in a pyrex tube at 600\(^\circ\)(Ref 1). Used in fire extinguish-
ers and refrigerants.

Calcium Fluoride (Fluorite or Fluorspar), \( \text{CaF}_2 \), mw 78.08, wh pdr, sp gr 3.18 at 20\(^\circ\), mp 1330\(^\circ\); nearly insol in w; sl sol in alc; reacts with hot concd sulfuric acid to liberate HF. Can be prep'd by powdering pure fluorite or by the interaction of soluble Ca salt and NaF. Used in manuf of HF, ceramics, smelting, cements, etching of glass, etc. Clear cryst is used in optical equipment. Was used by E. Turpin in exps named "Fluorine", described in Vol 6, under "Explosifs de Turpin".

Calcium Fluorosilicate (Calcium Silico-
fluoride), \( \text{CaSiF}_6 \), mw 182.17; wh cryts, sp gr 2.662 at 17.5\(^\circ\) and \( \text{CaSiF}_6 \cdot 2\text{H}_2\text{O} \), mw 218.20, wh crys, sp gr 2.254; v sl sol in w. Can be prep'd by the action of fluorosilicic acid on Ca carbonate, followed by crystn. Used in ceramics.

Carbon Tetrofluoride or Tetrofluoromethane.
See Vol 2, p C64-L. It is manuf'd by the E.I. duPont & Co, under the Trademark "Freon-14" or "F-14". See also CondChemDict (1961), 515-R, under FREON; (1971), 857-R (Tetra-
fluoromethane)

Carbonyl Fluoride or Carbon Oxyfluoride
(Fluoromonyl Fluoride), \( \text{COF}_2 \), mw 66.01, colorless, very poisonous gas, unstable in presence of w; sp gr 1.139 at -114\(^\circ\); fr p -114\(^\circ\), bp -83\(^\circ\). Can be prep'd by action of Ag fluoride on CO. Used in org synthesis; suggested as military poison gas.

Chlorine Fluoride. See Chlorine Trifluoride

Chlorine Trifluoride, \( \text{ClF}_3 \), mw 92.46; nearly colorless or pale grn gas; fr p -83\(^\circ\), bp +11.3\(^\circ\). Extremely reactive, comparable to fluorine; reactions with org comnds and with w take place with expl violence. Can be prep'd in 99% purity by reaction of chlorine and fluorine at 280\(^\circ\) and condensation of the product at -80\(^\circ\). Used as oxidizer in proplnts, in incendiaries and for cutting oil well tubes.

Chlorobenzotrifluorides, \( \text{Cl.C}_6\text{H}_4\text.CF}_3 \), mw 180.56. The following isomers exist: o-Chlorobenzotrifluoride, o-Chlorotrifluoromethylenzene or o-Chloro-a.a.a-trifluorotoluene, colorless liq with aromatic odor, sp gr 1.379 (15.5\(^\circ\)/15.5), fr p -7.4\(^\circ\), bp 152\(^\circ\) (760mm), nD 1.456 at 20\(^\circ\); sp 59\(^\circ\)C (closed cup). Can be prep'd by reaction of 2-chloro-
1-trichloromethylbenzene, HF in the presence of PCl₅ & Sb(V) fluoride chloride. Used as intermediate, solvent and dielectric liquid m-Chlorobenzotri fluoride, m-Chlorotri fluoromethylbenzene or m-Chloro-a,a,a-trifluorotoluene, colorless aromatic liq, sp gr 1.351 at 15.5°/15.5, fp -36°, bp 139.3°(760mm), nD 1.446 at 20°, fl p 37°C(closed cup). Can be prepd from Cl & benzo tri fluoride in the presence of FeCl₂ (Ref 1). Used in pharmaceuticals, dielectric and insecticides p-Chlorobenzotrifluoride, p-Chlorotri fluoromethylbenzene or p-Chloro-a,a,a-trifluorotoluene, colorless liq w aromatic odor, sp gr 1.353(15.5°/15.5), fp p -36°, bp 139.3°, nD 1.446 at 20°, fl p 37°C(closed cup). Can be prepd by heating 4-chloro-1-trichloromethyl benzene with SbF₅ (Ref 1). Uses: same as for m-Chlorobenzotri fluoride

1-Chloro-1,1-difluoroethene (1,1-Difluoro-1-chloroethane) (Genetron-142-B, Trademark of Esso Standard), CH₃CFC₂; mw 100.50; colorless, flammable gas; sp gr 1.194 at -9°, fp p -130.8°, bp -9.2°; insol in w. Can be prepd by chlorinating 1,1-difluoroethane in UV light. Used as solvent, aerosol propellant & refrigerant; also for prepn of fluorocarbon plastics

1-Chloro-2,2-difluoroethene or 2,2-Difluoro-chloroethane, F₂H₂.C.H₂.Cl; mw 100.50; colorless gas, sp gr >1, bp 36°. Can be prepd by prolonged heating of 1,1,2-trichloroethane with HF & HgO in an autoclave at 95°(Ref 1)
Refs: 1) Beil 1, 83, 983 & <138>  2) CondChemDict (1961), not listed

Chlorodifluoromethane or Difluorochloromethane ("Freon-22" or Fluorocarbon 22), CH₂CIF₂, mw 86.48, colorless, nonflammable gas; sp gr ?, fp p -160°, bp -40.8°. Can be prepd by reaction of chloroform with anhyd HF with Sb chloride catalyst. Used in aerosol propellant & refrigerant; also for prepn of tetrafluoroethylene polymers

1-Chloro-1,2,2-trifluoroethene or 1,2,2-Trifluoro-1-chloroethane, F₃H₂.C.H₂.FCl; mw 118.49, colorless liq, sp gr 1.365 at 0°, bp 17°; v sol in alc. Can be prepd from acetylene-tetrachloride & SbCl₅ + SbF₅. (Ref 1)
Refs: 1) Beil 1, 83 & <138>  2) Lange (1961), 704

2-Chloro-1,1,2-trifluorothylenne (CFE) or 1,1,2-Trifluoro-2-chloroethene, CFC₂:F₂; mw 116.48; colorless, flammable gas, fp p -157.5°, bp -27.9°; departs by w. Can be prepd from chlorotri fluorooethane and zinc. Used for polymerization to colorless oils, greases and waxes; also as refrigerant

Chlorotrifluoroethylene Resins. Polymers of CFE characterized by high degree of chemical inertness. Virtually unaffected by inorganic acids, alkalies, oxidizing agents, and most organic solvents. Typical commercially available materials are: "Fluorothen", "Halon" (Trademark of Allied Chemical Corp, Plastics Div, New York, 10006 and "Kel-F" (Trademark of Minnesota Mining & Mfg Co)
Ref: CondChemDict (1961), 267-R; also 507-R ("Fluorothene"); 559-L ("Halon") and 639-R ("Kel-F"); (1971), 208-R

Chlorotrifluoromethane or Trifluoromono-chloromethane ("Freon-13"), CCl₃F, mw 104.47; colorless, non-toxic, nonflammable gas with etheral odor; fp p -181°, bp -81.4°. Can be prepd from dichlorodifluoromethane in vapor phase with AlCl₃ catalyst. Used as a refrigerant- also for hardening of metals and in pharmaceutical processing; and as dielectric & aerospace chemical
Refs: 1) Beil 1, <42>  2) CondChemDict (1961), 267-R; (1971), 208-R

Chlorotrifluorooctfluoromethyl benzene. See under Chlorobenzotrifluorides in this Section
Chlorotrifluorotoluene. See under Chlorobenzotrifluorides in this Section

Chromic Fluoride or Chromium Trifluoride, \(\text{CrF}_3\), mw 109.01; gm crystals, sp gr 3.78, mp \(>1000^\circ\), bp – decomp; sol in w & acids; insol in alc. Can be prepd by the interaction of Cr hydroxide and HF. Used in moth-proofing woolen fabrics. Forms hydrates \(\text{CrF}_3\cdot4\text{H}_2\text{O}\) & \(\text{CrF}_3\cdot9\text{H}_2\text{O}\).

Ref: CondChemDict (1961), 273-L & R; (1971), 212-L

Cobaltous Fluoride or Cobalt Diffluoride, \(\text{CoF}_2\), mw 96.94, red-rose crystals or powd, mp ca 1200\(^\circ\), bp 1400\(^\circ\); sol in cold w & hydrofluoric acid; decomp in hot w; highly toxic & irritant. It forms a hydrate, \(\text{CoF}_2\cdot2\text{H}_2\text{O}\). Ammine complexes can be prepd from the hydrate.


Cobalt Trifluoride, \(\text{CoF}_3\), mw 115.94; lt-brn, free-flowing pdr; sp gr 3.88; reacts with w to form bk ppt of cobaltic hydroxide; unstable in moist air. Can be prepd from Co & ClF \(_3\) (Ref 1)

Used as a fluorinating agent


Copper Fluoride, \(\text{CuF}_2\cdot2\text{H}_2\text{O}\); mw 137.57; blue, poisonous crystals; sp gr 2.9; sl sol in w; sol in acids. Can be prepd by treating Cu carbonate with qaq HF, followed by cryst.

Used in ceramics and enamels

Ref: CondChemDict (1961), 301-R; (1971), 235-L

Copper Fluosilicate or Copper Silicofluoride, \(\text{CuSiF}_4\cdot4\text{H}_2\text{O}\); mw 277.72; blue, hygroscopic, poisonous crystals; sp gr 2.158, mp – decomp; sol in w, sl sol in alc. Can be prepd by interaction of Cu hydroxide and hydrofluosilicic acid. Used for treating grape vines for "white disease" and for dyeing and hardening white marble (Ref 1)

Lange (Ref 2) also lists \(\text{CuF}_2\cdot\text{SiF}_6\cdot0.6\text{H}_2\text{O}\), mw 313.73, blue, delq crystals, sp gr 2.158 at 19\(^\circ\); sol in w.

Cyanogen Fluoride or Fluorine Cyanide, FCN, mw 45.02; colorless, very irritant gas; forms a white pulverulent mass if cooled strongly & sublimes at \(-72^\circ\); insol in w. Can be prepd by interaction of AgF and cyanogen iodide. It attacks glass container under influence of light. Used in org synthesis and as a military poison gas (lachrymator)


1,1-Dibromo-2,2-difluoroethane or 2,2-Difluoro-1,2-dibromoethane, BrHC\(\text{CF}_2\)F; mw 223.87; colorless liq, sp gr 2.312 at 20\(^\circ\), bp 107.2\(^\circ\) (760mm); insol in w. Can be prepd by fluorination of 1,1,2,2-tetramethoxyethane with anhyd HgF \(_2\) at 150–60\(^\circ\) (Ref 1)


1,2-Dibromo-1,1-difluoroethane or 2,2-difluoro-1,1-dibromoethane, F\(_2\)BrC\(_2\)H\(_2\)Br, mw 223.87; colorless liq, sp gr 2.242 at 12.2\(^\circ\), fr p \(-56.5^\circ\), bp 93\(^\circ\) (760mm); insol in w. Can be prepd by reaction of 1,1-difluoromethylen & Br in acetic acid (Ref 1)

Ref: 1) Beil 1, 92, (29), [64], [189] & <160> 2) Lange (1961), 502 3) CondChemDict (1961), not listed

Dibromodifluoromethane, CF\(_2\)Br\(_2\), mw 129.93; colorless, poisonous, heavy liq; sp gr 2.286 at 15/4\(^\circ\), fr p \(-141^\circ\), bp \(+23.2^\circ\), mp 1.399 at 12\(^\circ\); insol in w; sol in methanol & eth. Can be prepd by vapor phase bromination of difluoromethane (Ref 1). Used in prep of quaternary Amm compds, synthesis of dyes and in pharmaceuticals


1,1-Dichloro-2,2-difluoroethane or 2,2-Difluoro-1,1-dichloroethane, F\(_2\)HC.C\(_2\)Cl\(_2\); mw 134.95; colorless liq, sp gr 1.494 at 17\(^\circ\), bp 80\(^\circ\); insol in w, miscible with alc & eth. Can be prepd by photochlorination of 1,1-difluoroethane at 200\(^\circ\) (Ref 1)
Refs: 1) Beil 1, 85, (24), [55], 1151 & <135> 2) Lange (1961), 502

1,2-Dichloro-1,2-difluoroethylene or 1,2-Difluoro-1,2-dichloroethylene, FCl:CICl, mw 132.93; colorless gas, fr p -112°, bp 20.9°. Can be prep'd by glycol heating 1,2-difluoro-1,1,2,2-tetrachloromethane with Zn in abs alc to give a mixt of cis & trans forms (Ref 1)


Dichlorofluoromethane or Fluorodichloromethane (Freon 21 or "Genetron-21 - Trademark of Esso Standard), CHClF; mw 102.93; colorless, non-flammable gas; sp gr 1.426 at 0°; fr p -135°, bp 8.9°; insol in w; sol in alc & in eth. Can be prep'd by reaction of chlorofom & hydrogen fluoride (Ref 1). Used as solvent, aerosol propellant, refrigerant, in fire extinguishers and in fluorocarbon plastics


s-Dichlorotetrafluoroethane or Tetrafluoro-1,2-dichloroethane (Fluorocarbon-114 or "Freon-114"), CCIF₂₃CCF₂; mw 170.93; colorless, nearly odorless gas, liq at -94°, bp 3.55°; critical pressure 32.3 atm. Can be prep'd by treating perchloroethylene with hydrogen fluoride (Ref 1). See Ref 2 for another method of prep'n. Used as aerosol propelant, solvent, fire extinguisher, refrigerant or solvent


Difluorenylidenehydro-sym-tetrazine. See Vol 5, p D1258-L

Difluorobenzene and Derivatives. See Vol 5, pp D1258-R & D1259-R

2,2-Difluoro-1-bromomethane. See 1-Bromo-2,2-difluoroethane in this Section

1,1-Difluoro-1-chloromethane. See 1-Chloro-1,1-difluoroethane in this Section

2,2-Difluoro-1-chloromethane ("Genetron-142B" - Trademark Esso Standard). See 1-Chloro-2,2-difluoroethane in this Section

Difluorochloromethane. See Chloroddifluoromethane in this Section

Difluorodibromomethane. See Dibromodifluoroethane in this Section

Difluorodibromomethane. See Dibromodifluoroethane in this Section

2,2-Difluoro-1,1-dichloroethane. See 1,1-Dichloro-2,2-difluoroethane in this Section

1,2-Difluoro-1,2-dichloroethylene. See 1,2-Dichloro-1,2-difluoroethylene in this Section

Difluorodichloromethane. See Dichlorodifluoromethane in Vol 5 of Encycl, p D1209-L and under "Freon-12" in CondChemDict (1961), 515-L, under "FREON"

Difluorodiphenyltrichloromethane (DFDT) or 1,1,1-Trichloro-2,2-bis(p-fluorophenyl) -ethane, (FC₄H₄)₂CHCCl₃; mw 290.57. Fluorine analog of dichlorodiphenyltrichloromethane (DCDT), mis-named DDT. DFDT first developed in Germany; wh solid with faint odor resembling ripe apples, mp 45.5°; insol in w; sol in acetone, eth, benz, CCl₄, kerosene, dioxane & pyridine. Can be prep'd by condensing choral and fluorobenzene in the presence of sulfuric or chlorosulfonic acid. Used as poison and pesticide

Note: Accdg to USPublicHealthService it is less poisonous to warm-blooded animals and fish than DDT, but does not have a long re-
sidual value. It does not have broad killing power of DDT toward all insects but is more effective against some flying insects, especially house flies.


1,2-Difluoroethane or Ethylene Fluoride,

**F**<sub>2</sub>H<sub>2</sub>C.H<sub>2</sub>F; mw 66.05; colorless gas; bp 31° at 750mm press; d 1.024 at 10°, op 1.3014 at 12°; prep by reacting ethylene bromide & AgF and by other methods (Ref 1)

Refs: 1) Beil 1, 82, [131] & <121> 2) Lange (1961), 502

1,1-Difluoroethylene, Vinylidene Fluoride or 1,1-Difluoroethane ("Geneton-1132A" — Trademark of Esso Standard), H<sub>2</sub>CCF<sub>2</sub>; mw 64.04; colorless gas, fr -144° at 1 atm, bp -83°; si sol in w; sol in alc, eth & chlf. Can be prep by adding HF to acetylene. It is a monomer of growing importance. Used in aerosol propellants, refrigerants and for prep of fluorocarbon plastics.


1,2-Difluoro-1,1,2,2-tetrachloroethane or 1,1,2,2-Tetrachloro-1,2-difluoroethane ("Freon-BF"), FCl<sub>2</sub>C.CCl<sub>2</sub>F; mw 203.85; colorless crysts, sp gr 1.645 at 20°/4, mp 24.7°, bp 92.8°; insol in w; sol in alc, eth & benz. Can be prep by heating dichloro-1,2-difluoroethane at 150° (Ref 1). Used as a solvent and as a flash point retarder for hydrocarbons and higher boiling solvents.


Dinitrogen Difluoride or Difluorodinitrogen,

N<sub>2</sub>F<sub>2</sub>, mw 66.02; gas which can exist as cis & trans isomers; compd may be toxic. Trans form is used for prep of ionic fluorine compounds; cis form used as polymerization initiator.

Refs: 1) Mellor, not found 2) Gmelin-Kraut Syst Number 5 (1959), 246 3) CondChemDict (1961), 805-L (Mentioned as powerful oxidizer suitable for both liquid and solid rocket propellants); (1971), 299-R (Difluorodiazine)

Dinitrogen Tetrafluoride or Tetrafluorodinitrogen, N<sub>2</sub>F<sub>4</sub>, mw 132.04; colorless mobile liq or gas, bp -73° heat of vaporization 3170 cal/mol; toxic & irritant; explodes in contact with reducing agents at high press. Can be prep by reaction of nitrogen trifluoride with As at 250-300°; some fluorimide (HNF<sub>2</sub>) is produced as by-product. Used as oxidizer in fuels for rockets, missiles and in org synthesis.


Ethylene Fluoride. See 1,2-Difluoroethane

Ethylene Tetrafluoride. See in this Vol, p E291-L

Ethyl Fluoride. See Fluoroethane

Ethylfluoriformate, C<sub>2</sub>H<sub>5</sub>COOF, mw 92.07; liquid, extremely irritant, sp gr 1.11 at 33°; fr p 20°, bp 57°. Can be prep by interaction of ethylchloroformate and thallium fluoride.

Refs: 1) Beil, not found 2) CondChemDict (1961), 470-L; (1971), 368-L

Ferric (or Iron) Fluoride, FeF<sub>3</sub>, mw 112.85, gm crysts, sp gr 3.18; sol in w & in acids. Can be prep by the oxide in aqueous HF. Used in ceramics (porcelain pottery)

Forms the hydrate, FeF<sub>3</sub>·4H<sub>2</sub>O


Ferrous Fluoride, FeF<sub>2</sub>·2H<sub>2</sub>O, mw 237.98, gm cryst; sol in acids & sl sol in w; its anhy-
drous salt has sp gr 4.09. Can be prep'd from
the metal or chloride by reaction with HF. Used
in ceramics
Refs: 1) Gmelin-Kraut, Syst Number 59, Teil
B (1932), 175 2) CondChemDict (1961),
493-R & 494-L; (1971), 386-R 3) Kirk &
Ohmer 9 (1966), 625

Fluobenzene. See Fluorobenzene

Fluoboric Acid. See Fluoroboric Acid

Fluochrome. See Fluochrome

Fluocompounds. See Fluocompounds

Fluorimide, HNF 3, mw 53.02; colorless liq,
fr p –131°, bp –23°; vapor pressure calecd by
Clauss–Clapeyron eqn: logP (mm) = –1298/T +
8.072; heat of vaporization (calcd) 5940cal/mole;
critical temp 93°

Was obtd during the reaction of nitrogen
trifluoride (NF 3) with As at 250–300° to pro-
duce dinitrogen tetrafluoride (N 2 F 4 )

Because of occasional explns, both solid
and liquid HNF 3 should be handled with caution
Refs: 1) Gmelin-Kraut Syst Number 5 (1959),
249 2) A. Kennedy & C.B. Colburn, JACS
81, 2906–07 (1959) & CA 53, 15844 (1959)
3) CondChemDict (1961), not found 4) Kirk
& Ohmer, not found 5) CondChemDict (1971),
not found

Fluorine (Explosif de Turpin). See under
Explosifs de Turpin in this Vol, pp E366-L
to E367-R

Fluorine Azide or Azidofluoride. See Vol 1,
p A536-L, under AZIDES, INORGANIC

Fluorine Bromide. See Bromine Trifluoride
in this Section

Fluorine Chloride. See Chlorine Trifluoride
in this Section

Fluorine Compounds (Danger of Explosion).
Accdg to private communication of Dr J.V.R.
Kaufman, formerly of PicArsn and the Minnes-
nesota Mining and Manufacturing Co, Minneapolis,
Minnesota, caution should be exercised when
dealing with some of the fluorine compounds.
It was claimed that fully fluorinated lower
members, such as CH 3 CH 2 N F 2 are explsively
unstable and that treatment of fully fluorinated
lower members, such as CF 3 COOH with LiAl
hydride causes expln. Another fluorine compd
which might cause an expln is Ethylene Tetra-
fluoride, which is described in this Vol, p E291-L

Fluorine Cyanide. See Cyanogen Fluoride

Fluorine Fluorosulfate, SO 3 F 2, mw 118.07;
decomp at 200° into O & SO 2 F 2
Refs: 1) Gmelin-Kraut, not found
Note: Acqcd to Dr George H. Cady of the Univ
of Washington in Seattle, the compd is prob-
ably expl. He said that during the prep of
about 500g of peroxysulfuryl difluoride
(SO 3 F 2), about 200g of SO 3 F 2 was formed.
Sulfuryl fluoride (SO 2 F 2) also formed, and also
some unidentified compds. The by-products
were distilled into a cold, clean, dry steel

cylinder strong enough to withstand pressure
of 135 atm. (The vapor press of SO 3 F 2 at RT
is ca 10 atm.) When cylinder was brought to
RT, the contents of the cylinder exploded. Dr
Cady thought that violence of expln suggested
a chem expln rather than a simple rupture by
gas pressure
Ref: Anon, C&EN, Feb 21 (1966), p 40-R,
under BRIEFS

Fluorine Nitrate, Nitrogen Trioxylfluoride or
Nitrosyl Hypofluorite, NO 3 F, mw 81.01; color-
less gas, fr p –175°, bp –45.9°, Trouton Con-
stant 20.8. Either liquid, solid or gas, it
explodes readily and violently, and often for
no apparent reason

Was first obtd in 1935 by Cady (Ref 1a) on
 treating 3-normal nitric acid with fluorine.
Ruff & Kwansnick (Ref 2) showed that it was
better to use 100% nitric acid at RT in a quartz
apparatus. It can also be made by the action
of fluorine on K nitrate

It is a very powerful oxidizer which deflag-
rates upon contact with reducers such as
alcohol, ether & aniline (Ref 7)
Refs: 1) Gmelin-Kraut Syst Number 5 (1959),
254 1a) G.H. Cady, JACS 56, 2635 (1934)
2) O. Ruff & W. Kwansnick, AngewChem 48, 238
Fluorine Organic Materials. Experiments were conducted by placing small pieces of organic materials into 10g of liquid fluorine contained in a small Ni cylinder and surrounded by liquid N in a stainless steel beaker. While neoprene produced only a slight explosion, cotton gave an immediate violent expl with a brilliant white flame.

Refs: R.H. Lafferty Jr et al., C&EN 26, 3336 (1948) & CA 43, 406 (1949)

Fluorine Oxide, F₂O, mw 54.00, colorless gas or vey brn Lq, sp gr of liq at -190° 1.65, fr p -224°, bp -145°; v sl sol in w. Can be prep'd by hydrolysis of F or by electrolytic methods (Ref 1). It has attracted attention in recent years as an ingredient of high-energy rocket-propellant systems (Ref 3).


Fluorine Oxonide or Trioxgen Difluoride (Ozonofosinid in Ger), F-O₃-F, mw 85.00; solid at bp of nitrogen (77.0K) and liq at bp of oxygen (90.0K); decomposes at 120.0K. Was prep'd by an electric discharge process using a ratio of 3/2 oxygen/fluorine in a tube cooled by liq nitrogen (Ref 6). It is very reactive substance. A trace amt (0.05% by wt) of F₂O₃ dissolved in liq oxygen makes the resultant oxidizer capable of hypergolic ignition with common hydrocarbons, amine base fuels or hydrogen and provides more stable combustion.


Fluorine Peroxide or Dioxogen Fluoride, F-O₂-F, mw 70.00, brn gas, red liq or om solid; d of liq 1.45 at -57°, d solid 1.92 at -165°; fr p -163.5°, bp -57° best prep'd by passing a 1/1 mixt of gaseous O₂ & F₂ at low press thru a high voltage electric discharge tube cooled by liq nitrogen (Ref 2). It is an extremely powerful oxidizing-fluorinating agent and reacts explosively with oxidizing materials.


Fluorines of Turpin. See under Explosifs de Turpin in this Vol, pp E366-L to E367-R

Fluorite. See Fluorspar in this Section.

Fluoroacetylene, FC=CH, mw 44.03, colorless gas or liquid; fr p below -196°, bp below -80°. Was prep'd in nearly quant yield by pyrolysis of fluoroacetaldehyde in a SiO₂ tube at 650°C and 5-7mm Hg. Liquid fluoroacetylene is treachernously explosive but the vapor is stable (Refs 1 & 2).

It slowly condenses to the trimer 1,2,4-trifluorobenzene, C₈H₆F₃.

Hg & Ag salts of C₈H₆F₃, prep'd by passing
its vapor thru aq solns of Hg or Ag nitrates are stable to shock but decom on warming
Refs: 1) Beil 1, 957> 2) W.J. Middleton & W.A. Sharkey, JACS 81, 803–04 (1959) &
CA 53, 14028 (1959) 3) CondChemDict (1971), not found

Fluoroalcohols. A group of fluorine contg alcohols are available commercially having the
general formula H(CF\textsubscript{2}CF\textsubscript{2})\textsubscript{n}CH\textsubscript{2}OH, in which n=1 to 8. They include alcs contg
C\textsubscript{3}, C\textsubscript{4}, C\textsubscript{5}, C\textsubscript{6} & C\textsubscript{11}. Density of liquids
1.48–1.66, \(n_D 1.318–1.320\) (lowest of all known org compds). Derived by free radical
telomization of tetrafluoroethylene with methanol. Used as solvents and in org
synthesis
Refs: 1) CondChemDict (1961), 506-L
2) Kirk & Othmer (1966), 751 (Fluoroethanols)

Fluorouranium of Potassium or Potassium
Fluorouranlate (Ger, Kyrolith), K\textsubscript{3}AlF\textsubscript{6},
mw 258.27; crys, mp 1025°, heat of formation
44.4 kcal/mole; prepd by heating KF & AlF\textsubscript{3} to between 565–840° (Ref 1). Found as a
mineral in Germany. Has been used in
some propellants and pyrotechnic compns
For example, Brit Cordite N contd NC
(13.1% N) 19.0, NG 18.5, NGu (Picrite) 54.7,
&Centr 7.5 & K\textsubscript{3}AlF\textsubscript{6} (called Cryolite in
Ref 2) 0.3% with added chalk 0.15%. A
similar proplnt known as Type HPM contd:
NC (13.1% N) 18.7, NG 18.2, NGu 53.8; &
Centr 7.5, K\textsubscript{3}AlF\textsubscript{6} 0.3 & K sulfate 1.5\
with 0.15% chalk added
When incorporated in pyrotechnic compns, it probably imparted pink coloration since
Na\textsubscript{3}AlF\textsubscript{6} imparted yellow light
The following proplnts were described in a British Report:
Type ASN: NC (12.2% N) 50.00, NG 36.25,
&Centr 5.75, DBuP 8.7 & K\textsubscript{3}AlF\textsubscript{6} 4.5%
(Do not confuse with ASN described in Vol
1, p A496-L)
Type HSCK: NC (12.2% N) 49.5, NG 47.0
& &Centr 3.5, with K\textsubscript{3}AlF\textsubscript{6} 2.25% added
Refs: 1) Gmelin-Kraut Syst Num 35, Teil
B (1943), 450 2) R.A. Connor, Chief of
Div 8, "Summary Technical Report of Div 8,
NDRC", Vol 1 (1946), 107-L 3) Large
(1961), not found 4) CondChemDict (1961),
not found

Fluorurate of Sodium or Sodium Fluoro-
urate (Cryolite), Na\textsubscript{3}AlF\textsubscript{6}. To the brief
description given on p C567-L of Vol 3, the
following uses may be added:
US Cannon Propellants, M15 and M17, de-
scribed in Specification MIL-P-668A and in
Vol 2 of Encycl, p C34
US Cannon Proplnt M30, described in Spec
MIL-P-46489 and in Vol 2, p C34
US Cannon proplnts M31 & T29, described
on p C34. All of these proplnts contd 0.3%
Na\textsubscript{3}AlF\textsubscript{6}.
The following proplnts were listed in a British Report
Type N: NC (13.1% N) 19.0, NG 18.7, NGu
(Picrite) 55.0 & &Centr (Carbamite) 7.3%\
with Na\textsubscript{3}AlF\textsubscript{6} 0.3% added
Davis (1943), pp 63 & 70–1 lists pyro-
technic compns contg cryolite. Tesseract of
France introduced it at the time of WWII for
the yellow coloring of stars, lances and Bengal
lights. Other pyrotechnic uses and several
refs are given in Vol 3, p C567-L
See also Sax (1968), 1097 (Sodium Alu-
imium Fluoride) & CondChemDict (1971),
245-R (Cryolite)

Fluorobenzene and Derivatives
Fluorobenzene or Phenyl Fluoride, F.C\textsubscript{6}H\textsubscript{5}F,
mw 96.10, colorless liq with benz odor, sp
gr 1.0252 at 20°/4, fr p -41.9°, bp 84.9°,
& 1.4677 at 20°; nearly insol in w; mis-
cible with alc & eth. Can be prepd by di-
azotizing aniline in anhyd HF followed by
controlled thermal decmp of the diazonium
fluoride (Ref 3). Used as identification re-
agent for plastic or resin polymers and as
insecticide intermediate
Refs: 1) Beil 5, 198, (108), [147] & [520]
3) Kirk & Othmer (1966), 783
(Compare with DiFluorobenzene, described in
Vol 5, p D1258-R)

Fluorobenzene or Nitrofluorobenzene,
(ortho-, meta- and para-), F.C\textsubscript{6}H\textsubscript{4}(NO\textsubscript{2}); mw
141.11, N 9.94%. Prepd by variety of nitra-
tion methods from fluorobenzene. Its para-
compd is described in Ref 1, as pale yel
crysts, mp 27°(21.5°), bp 206.7°

Fluoro-2,4-dinitrobenzene or 2,4-Dinitrofluorobenzene, F₈C₈H₆(NO₂)₃; mw 186.12, 
N 15.07%; OB to CO₂ 77.4%; liq, fr p 10–12°, bp 136–138° at 2mm press. Prepd 
by refluxing 2,4-dichlorobenzene over KF 
or by nitration with mixed nitric-sulfuric 
and fluorobenzene

It may be a mild expl
Refs: 1) Beil 5, 262 & (136) 2) Same as 
Ref 2 of previous item
(Compare with Dinitrofluorobenzene in 
Vol 5, p D1259-L)

Fluoro-2,4,6-trinitrobenzene or 2,4,6-Trinitro- 
fluorobenzene (TNFB), F₈C₈H₆(NO₂)₃; mw 
231.13, N 18.20%, OB to CO₂ 45.0%; solid, 
mp 126°(Ref 6), mp 35°(Ref 4) (?). Prepd 
by treating 2,4,6-Trinitrochlorobenzene with 
NaF & HAc (Refs 2 & 3) or by nitration of 
2,4-Dinitrofluorobenzene with 60% oleum & 
sulfuric & fuming nitric acid (Ref 4)

Its prepns was investigated recently at 
PicArsn (Ref 5) and in Canada (Ref 6). It 
is an explosive

The method used at PicArsn for prep 
TNFB involved the nitrination of 2,4-dinitro-
fluorobenzene, but the attempts, based on 
literature references, were unsuccessful
Refs: 1) Beil, not found 2) L.G. Wesson, 
USP 2179605 (1940) & CA 34, 1852 (1940) 
3) V. Leonard, BritP 537010 (1941) & CA 36, 
1496 (1942) 4) G. Olah et al, ActaChim-AcadSciHung 
7, 431–42(1955) & CA 53, 
1195 (1959) 5) V.I. Siele & H.J. Maruguma, 
"Investigation of Synthetic Methods 
for Preparing the Fluoroderivatives of 
Symmetrical Trinitrobenzene", PicArsn TechRept 
2682, FREL, Project TB 3–0115B, Item D, 
Project 5A04–10–006, April 1960 6) H.L. 
Sharma et al, CanadChem 44(11), 1327–31 
(1965) & CA 65, 2154 (1966)
(Compare with 1,3-Difluoro-2,4,6-trinitro-
benzene in Vol 5, p D1259-L)

Fluorobenzoic Acid and Derivatives

Fluorobenzoic Acid, F₈C₈H₄·CO₂H; mw 140.11.
All three isomers are known: ortho, ndls/aq, 
mp 120–22°; meta, lits/aq, mp 124°; and para, 
mn/aq, mp 184–86°. Methods of prepns 
are described in Refs:
Refs: 1) Beil 9, 333, (136, 137), [220] &
[1324], 1327] 2) Lange (1961), 554

2-Fluoro-4-nitrobenzoic Acid,
F₈C₈H₄(NO₂)·CO₂H; mw 185.12, N 7.57%, 
crysts, mp 175°. Prepd by oxidation of 2-
fluoro-4-nitromuine
Refs: 1) Beil 9, [1762] 2) H. Goldstein & 
M. Urzvater, Helv 34, 1350–55 (1951) & CA 
46, 5553 (1952)

2- Fluoro-4,5-dinitrobenzoic Acid,
F₈C₈H₄(NO₂)₂·CO₂H; mw 230.13, N 12.19%, 
OB to CO₂ 62.6%; crysts, mp 137°. Prepd 
by nitrating with mixed nitric-sulfuric acid 
in presence of 2-fluoro-4-nitrobenzoic acid 
Refs: 1) Beil 9, not found 2) H. Goldstein 
& M. Urzvater, Helv 34, 1350–55 (1951) & CA 
46, 5553 (1952)

Fluoroborate (or Fluoborate) of Potassium. 
See Potassium Borofluoride in this Section

Fluoroborate (or Gluoborate) of Sodium. See 
Sodium Borofluoride in this Section

Fluoroboric (or Fluoboric) Acid, HBF₄, mw 
87.83; colorless clear, strongly acid liq; bp 
130°(dec); miscible with w & alc. Can be 
prepd by action of boric + sulfuric acid on 
fluorspar. Used for prepns of fluoroborates and 
stabilized diazo salts. Its specially purified 
sofit used in patented process for electrolytic 
brightening of Al 
Refs: 1) Gmelin-Kreut Syst Number 13 (1926), 
115 & 13 (1954), 189 2) CondChemDict 
(1961); 504-L 3) Kirk & Othmer 9(1966), 
Fluorocarbon Resins. This term includes: polytetrafluoroethylene, polymers of chlorotrifluoroethylene (fluorothene), vinylidene fluoride (H₂C₂F₂), hexafluoropropylene (C₃F₆) and similar compds. These polymers are thermoplastic, inert to chemicals and oxidation. They have high heat stability, retain their useful props at both extremely low and high temps, have high electrical resistance to moisture. The materials are available as resins, powders, and dispersions, and as films, sheets, tubes, rods and tapes. Some of them are rubber-like. Commercially available varieties are "Kel-F", "Teflon", "Fluroel", "Aclar" and "Halon". Ref: CondChemDict (1961), 506-R; (1971), 396-R

Fluorocarbons or Organic Fluorine Compounds. Compds of carbon and fluorine with or w/o hydrogen. They are analogs of hydrocarbons in which all, or nearly all, the hydrogen is replaced by fluorine. They are characterized by extreme chem inertness, do not burn, and are thermally stable to 500°F or more. Can be prep'd by various methods all based on the exchange of a halogen atom in an org compd for a fluorine atom in a fluorinating agent. The most common agents are fluorides of alkalie metals (Ref 7). General uses are as aerosol propitious, fire extinguishing agents, lubricants and hydraulic fluids, liquid dielectrics and coolants. There are also some special uses, such as binders in extended solid propellants. Refs: 1) C. Slesser & S.R. Schram, Eds., "Preparation, Properties and Technology of Fluorine and Organic Fluro Compounds", McGraw-Hill, NY (1951) 2) W.T. Miller, Jr., NatlNuclearEnergyService, Div VII, 1, 457-468 (1951) & CA 46 7988 (1952) (Numerous fluorocarbons were prep'd by polymerization of olefins; some of fluorocarbons proved to be explos sensitive to shock) 3) M.A. Rudner, "Fluorocarbons", Reinhold, NY (1958) (Properties, chemistry, processing, fabrication techniques, and final application of fluorocarbons) 4) CondChemDict (1961), 506-R (Properties and uses of fluorocarbons) 5) G.B. Rice et al, "Extudd Solid Propellants with Fluorocarbon Binders" (U), Naval-OrdnanceTestStation, NOTS TP 3042, Aug 1963; NAWEPB Rep, 8047 (Conf) (Not used as a source of info) 6) R.E. Banks, "Fluorocarbons and Their Derivatives", Oldbourne Press, London, 1966 7) Kirk & Othmer 9, 686-846 (1966) (Fluorine Compounds, Organic by E.T. McBea et al) 8) L.A. Wall, Ed, "Fluoropolymers", Wiley-Interscience, NY (1971) 9) CondChemDict (1971), 396-L


Fluorochemicals. Org compds, not necessarily hydrocarbons, in which a large percentage of hydrogen directly attached to carbon has been replaced by fluorine. The presence of 2 or more F atoms on a C atom usually imparts great stability and inertness to the compd and F usually increases the acidity of org acids. The following processes exist for their prep: a) Electrolysis of solns in HF; b) Replacement of Cl or Br by F with HF in the presence of a catalyst such as antimony trifluoride or pentafluoride; c) Addition of HF to olefins or acetylenes. Used as refrigerants, lubricants, aerosol propellants, fire extinguishents and inert plastics. Refs: 1) CondChemDict (1961), 507-L 2) D.N. Gray et al, "Research on the Synthesis of Fluorochemicals", APGC TR-59-30, Proj No 2858, Contract No AF08 (603)-4505, Denver Univ (July 1962) 3) CondChemDict (1971), 396-R

Fluorochemistry and Fluorometric Analysis Fluorochemistry is a term proposed in 1942 by J. de Ment for the branch of physical-chemical science embracing the theory and applications of luminescence (qv) and radia-
Fluorine (qv) to chemistry. (See also Fluoroscopy, Luminescence etc)

The science is based on the following laws:

1st law of fluorescence (J. deMent, 1942): Before emission can occur from a luminescent system, absorption must first take place.

2nd law (Sir G.G. Stokes, 1852): The energy released as luminescence from a body is always less than the energy absorbed for initial excitation.

3rd law (J. deMent, 1943): The absorption of radiation by a luminescent system is a quantum process involving one quantum per absorbing center; the yield of luminescence then, in the ideal case, being unity.

Fluorometric Analysis is the branch of analytical chemistry which determines the presence (and the amounts) of certain substances by exposing them to the action of ultraviolet rays (or of X-rays) and observing the fluorescence emitted by them.


Fluoro Compounds. Compounds contg fluorine show promise as oxidizers. Some fluorine compds presently under investigation include elemental F, halogen fluorides, nitrogen trifluoride, and oxygen difluoride. Fluorides are corrosive and often unstable. Hence, some emphasis is placed on compd stability. In rockets, oxide fuels offer a good balance between low molecular wt combustion products & high flame temp. Lithium fuels, such as LiF2, which utilize fluorine, are also of interest.


Fluorodichloromethane. See Dichlorofluoromethane in this Section

Fluoroethane or Ethyl Fluoride, H2C.CH2.F; mw 48.06; colorless gas, sp gr 1.7 (Air 1.0), fr p = 1.43.2°, bp = 37.7°; v sol in w & in alc. Can be prep'd by heating bromoethane & HgF at 110° (Ref 1). When heated to decom, it emits toxic fumes of fluorides.
Fluoromethane or Methyl Fluoride, CH₅F, mw 34.03; colorless gas, sp gr 0.877, mp -142°C, bp -78.2°C; sol in w. Can be prep'd from chloromethane & AgF at 225°C or from iodomethane & HgF₂ (Ref 1)

Refs: 1) Beil 1, 59, (8), [11], [33] & <22>
2) Lange (1961), 604 (Methyl Fluoride)
3) CondChemDict (1971), 397-L

Fluorometry is the branch of physics dealing with measuring of X-rays and other radiations by the fluorescence produced

(See also Fluorochemistry, Fluorescence, Luminescence, Radiation, X-rays)

Fluoro-Nitro Compounds. The prepns, structures, physical props & chem props of oxy-fluorides of N(NO₃) & nitrylhydofluorite (NO₂F); the prepns & props of NOF—HF adducts, the chemistry of NOF.HF, the NO₂F—HF system, reactions of NOF & NO₂F with acceptor fluorides; addn of NOF & NO₂F across double bonds; N,N-difluorohydroxylamines; and uses of NOx fluorides are discussed by Schnutzel (Ref 2)


Fluorophenol and Derivatives

Fluorophenol, F₆C₆H₄OH, mw 112.10. None described in Ref 3, but para- described in Ref 4 as wh cryst.s, sp gr 1.1889 at 56°C, mp 48.2°C (stable form), 28.5°C (unstable form), bp 185.6°C (760mm), 78°C (15mm); sol in w. Can be prep'd by heating 4-fluorophenyl acetate with conc HI (Ref 2)

Used as intermediate for pharmaceuticals & fungicides and as fungicide

All isomers are described in Refs 1, 1a & 2

Refs: 1) Beil 2, (97) & 4167 (ortho)
1a) Beil 6, (97), [169] & 1668 (meta)
2) Beil 6, 183, (98), [170] & 1669 (para)
3) Lange (1961), not found 4) CondChemDict (1961), 507-R (p-Fluorophenol); (1971), 397-L
Fluoronitrophenols or Nitrofluorophenols,
F.C₆H₄(NO₂)₂.OH; mw 157.11, N 8.92%. The following isomers are known:
3-Fluoro-2-nitrophenol, orn-yel ndls, mp 39° (Refs 1 & 6)
4-Fluoro-2-nitrophenol, yel crys (from alc), mp 73.7° (Ref 2)
5-Fluoro-2-nitrophenol, yel ndls (from petr eth), mp 32° (Ref 3)
6-Fluoro-2-nitrophenol, yel prisms (from diisopropyl eth), mp 90–91° (Ref 4)
5-Fluoro-3-nitrophenol, yel crys (from aq HCl or thru sublimation, mp 112° (Ref 4)
2-Fluoro-4-nitrophenol, ndls or tablets (from w), mp 117–18° (Ref 4)
3-Fluoro-4-nitrophenol, ndls (from w or petr eth), mp 42° (Refs 5 & 6)
Other props & methods of prepn are found in Refs

Fluorodinitrophenols or Dinitrofluorophenols,
F.C₆H₃(NO₂)₂.OH, mw 202.12, N 13.88%, OB to CO₂ –63.4%. The following isomers are known:
3-Fluoro-2,4-dinitrophenol, yel crys (from petr eth), mp 138–39°. Prep'd by stepwise nitration of m-fluorophenol (Refs 1 & 6)
5-Fluoro-2,4-dinitrophenol, ls-yel microcrystls (from petr eth), mp 138–39°; v sol in w; prep'd by nitrating 3-fluorophenol with mixed sulfuric-nitric acid at 10–15° and hydrolyzing the reaction product with steam (Refs 1 & 6)
6-Fluoro-2,4-dinitrophenol, yel crys (from alq alc or benzine), mp 102°; v sol in benz, MeOH & alc; mod sol in w; obt'd with other products by nitrating 2-fluorotoluene or 2-fluorophenol with mixed acid at –5 to 0° (Ref 2)
3-Fluoro-2,6-dinitrophenol, ndls (from petr eth), mp 68.5°; was prep'd by stepwise nitration of 3-fluorophenol or 5-fluoro-2-nitrophenol at 10–15° (Refs 3 & 6)
4-Fluoro-2,6-dinitrophenol, yel prisms (from CS₂), mp 50–50.2°; readily sol in eth & alc; sl sol in water; was prep'd by nitrating 4-fluorophenol with concd nitric & sulfuric acids and treating the reaction product with KOH (Ref 4)
3-Fluoro-2,4-dinitrophenol, plts (from water), mp 72–74°; was prep'd by nitrating 3-fluorophenol with mixed nitric-sulfuric acid (Ref 5). It forms a yel K salt

3-Fluoro-2,4,6-trinitrophenol, 3-Fluoropicric Acid or 2,4,6-Trinitrofluorophenol,
F.C₆H₃(NO₂)₃.OH, mw 247.13, N 17.02%, OB to CO₂ –35.6%; crys (from w), mp 173°. Prep'd by stepwise nitration of m-fluorophenol and by other methods (Ref 1). It may be a powerful explosive. It forms an Ag salt, yel ndls; readily sol in aq ammonia & in hot water

Fluoroscopy is the visual examination of X-ray shadow images by means of a fluorescent screen. It may be used for the inspection of light metal castings, some ammunition, castings of explosives etc. In this method, the images are formed directly on a screen and no films are required, which makes the cost of inspection lower than with ordinary X-ray examination
Refs: 1) Hack's (1944), 349

Fluorosilicates. Salts of Fluosilicic Acid, H₂SiF₆. See Aluminum-, Ammonium-, Barium-,Calcium-, Copper-, Lead-, Magnesium-, Potassium-, Sodium-, and Zinc Fluosilicates in this Section

Fluorosilicic (or Hydrofluosilicic) Acid, (Silicofluoric Acid), H₂SiF₆; mw 144.11; colorless, transparent, fuming, corrosive, poisonous liquid; attacks glass & stoneware; kept in wax, wood, or special plastic con-
tainers; sol in w. Obt as by-product of the action of sulfuric acid on phosphate rock conglutinates and silica or silicates. Also by action of water on tetrafluoride, SiF₄, which, in turn, is prep'd by action of HF on silica. Used for prep of fluosilicates of Amm, Ba, Cu, Mg, Pb & Zn; also to increase hardness in ceramics, in hardening of cement during building, preserving masonry and as disinfectant

**Fluoroethene.** A plastic polymer of trifluorochloromethane, C₂F₃Cl. Resistant to concd acids and alkalis up to 300°F. Swelled by some chlorinated hydrocarbons
Re: CondChemDict (1961), 507-R; (1971), 208-R

**Fluorotoluene and Derivatives**

*Fluorotoluene, F₅C₆H₄.CH₃; mw 110.13.* Three isomers α-, m- & p- are known. They are colorless lgs with bp's 113-140°, 115-160° & 116-170°, resp. All isomers are insol in w and sol in alc & eth. Can be prep'd from the corresponding toluene-diazonium-tetrafluoroborate

*Fluoro-mononitrotoluene, F₅C₆H₄(NO₂).CH₃; mw 155.13, N 9.03%.* The 3-Fluoro-2-nitro-; 4-Fluoro-2-nitro-; 5-Fluoro-2-nitro-; 6-Fluoro-2-nitro-; 4-Fluoro-3-nitro-; 2-, 4- & 6-Fluoro-3-nitro-; and 2- & 3-Fluoro-4-nitrotoluenes are all described in Ref 1. Ref 2 also describes 2-Fluoro-4-nitrotoluene
Refs: 1) Beil 6, 326, (161), [250, 251] & [742, 743] 2) H. Goldstein & M. Urvater, Helv 34, 1350-55 (1950) & CA 46, 5553 (1952) (Its oxidation produced 2-fluoro-4-nitrobenzoic acid)

**NOTE:** No higher nitrated derivs of Fluorotoluene were found in the literature

**Fluorotrichloromethane or Trichloromonofluoromethane** ("Freon-11" or "Freon-MF", Solvent), CCl₃F, mw 137.38; colorless, volatile liq, sp gr 1.494 at 17.2°, fr p -111°, bp 23.7°, crit press 43.2 atm. Insol in w; miscible with alc & eth. Prep'd from CCl₄ & HF in the presence of fluorinating agents, such as antimony tri- and penta-fluorides. Used as aerosol prop, refrigerant and fire extinguisher
Refs: 1) Beil 1, 64, [63] & <54> 2) CondChemDict (1961), 1161-R (Trichlorofluoromethane) and 515-L & 516-L under "FREON"; (1971), 887-L

**Flurospar or Fluorite** See under Calcium Fluoride in this Section

**Fluorylv Porchloate or Perchloryl Oxyfluoride.** See Fluotine Perchlorate in this Section

**Fluosilicates.** See Fluosilicates in this Section

**Fluosilicic Acid.** See Fluosilicic Acid in this Section

"FREON". Trademark of E.I. duPont de Nemours & Co, Inc, Wilmington, Del for a line of fluorinated hydrocarbons used as propellants, refrigerants, blowing agents, fire extinguishers and solvents

The following "Froens" are listed in Ref, pp 515-L to 516-L & other pages
"Freon-11" or "F-11" or Trichloromonofluoromethane. See Fluorotrichloromethane in this Section
"Freon-12" or "F-12". See Dichlorodifluoromethane in Vol 5 of Encycl, p D1209-L
"Freon-13", "F-13" or Monochlorotrifluoromethane. See Chlorotrifluoromethane in this Section
"Freon-13B1", "F-13B1" or Monobromotrifluoromethane. See Bromotrifluoromethane in this Section
"Freon-14" or "F-14" or Tetrafluoromethane. See Carbon Tetrafluoride in Vol 2 of Encycl, p C64-L.
"Freon-21". See Dichlorofluoromethane in this Section
"Freon-22" or "F-22" or Monochlorodifluoromethane. See chlorodifluoromethane in this Section
"Freon-113" or "F-113". See Trichlorotrifluoroethane in this Section
"Freon-144" or "F-144". See Dichlorotetrafluoroethane in this Section
"Freon-C318". See Octafluorocyclobutane in this Section
"Freon-BF", Solvent or Tetrachlorodifluoroethane. See 1,2-Difluoro-1,1,2,2-tetrachloroethane in this Section
"Freon-MF", Solvent or Trichloromonofluoromethane. See Fluorotrifluoromethane in this Section
"Freon-TF", Solvent. See Trichlorotrifluoroethane in this Section
Refs: CondChemDict (1961), 515-L to 516-L and on pages indicated under their chemical names; (1971), 402-R

Hydrazine Tetrafluoride. See Tetrafluoro-hydrazine in this Section

Hydrofluoric Acid. See the first item described under FLUORINE DERIVATIVES in this Section

Hydrofluorosilicic (or Hydrofluosilicic) Acid. See Fluorosilicic Acid in this Section

Hydrogen Fluoride. Same as Hydrofluoric Acid, Anhydrous, described in this Section

Iodine Fluoride or Iodine Pentfluoride, IF$_5$, mw 221.91; colorless, fuming liq; sp gr 3.29 at 0° (Ref 3), 3.189 at 25° (Ref 3), f t p -8° (Ref 3), -9.4° (Ref 3), bp 97° (Ref 2), 98° (Ref 3); decompy by w & attacks glass. Can be prep by igniting iodine in a stream of fluorine. Used as an incendiary agent & as fluorinating agent

Iron Fluoride. See Ferric Fluoride in this Section

Potassium Fluoride. See Potassium Fluoride in this Section

Lead Fluoride, PbF$_2$, mw 245.21; wh crs, sp gr 8.24, mp 855°, bp 1290°; sl sol in w; sol in nitric acid; insol in NH$_3$ & acetone. Can be prep by the reaction of F with Pb salts, and by reaction of HF with Pb salts (Ref 1). Used in electronic & optical applications

Lithium Fluoride, LiF, mw 25.94; wh cu crs, poisonous, sp gr 2.295 at 21.5°, mp 870°, bp 1670°; sl sol in w and does not react with it at red heat; insol in alc & acetone; sol in HF. Can be prep by treating lithium carbonate with HF. Used in welding and soldering flux, in ceramics and for prep of synthetic crystals in IR & UV instruments; proposed for use in space components

Magnesium Fluoride or Magnesium Sellaite (Magnesium Flux), MgF$_2$, mw 62.32, wh crs; sp gr 3.0, mp 1263°, bp 2239°; exhibits fluorescence under elec light; insol in alc; nearly insol in w; sol in nitric acid. Can be prep by adding hydrofluoric acid to Mg salt soln. Used in ceramics & glass
Magnesium Fluosilicate or Magnesium Silico-fluoride, MgSiF₆⋅6H₂O; mw 274.51; wh, ef- florescent crts; sp gr 1.788 at 17.5°/4, mp – decmp on heating to 120°; sol in w.
Can be prep’d by treating Mg hydroxide or carbonate with hydrofluosilicic acid. Used in ceramics, concrete hardening, waterproofing & mothproofing

Magnesium Fluoride. See Magnesium Fluoride in this Section

Manganic Fluoride, MnF₃, mw 111.94, red, poisonous crts; sp gr 3.54; mp – decmp on heating; sol in acids; decom by w. Can be prep’d by dissolving Mn in dil HF cont’d in a silver basin (Ref 2) and by other methods. Used as a fluorinating agent

Manganous Fluoride, MnF₂, mw 92.94, reddish pdr, sp gr 3.98, mp 8.56°; sol in acids; insol in w, alc & ether. Can be prep’d by the action of HF on manganous hydroxide and by other methods (Ref 2)

Mercuric (or Mercury) Fluoride, HgF₂, mw 238.61, transparent, poisonous crts; sp gr 8.95 at 15°, mp 645°(dec); sol in HF & dil nitric acid; decom by w. Can be prep’d by treating mercuric oxide with HF. Used in synthesis of org fluorine compds

Methyl Fluoride. See Fluoromethane in this Section

Molybdenum Fluoride or Molybdenum Hexa-fluoride, MoF₆, mw 209.95, wh crts melting at 17.5°; sp gr of liq about 2.5; bp 35°; reacts readily with w. Can be prep’d by direct action of fluorine on Mo metal. Used in the separation of Mo isotopes

Natrium Fluoride. See Sodium Fluoride in this Section

Nickel Fluoride, NiF₂, mw 96.71, grn pdr, mp 1100°; sp gr 4.63; sl sol in w; insol in alc, eth & NH₃. Can be prep’d from Ni carbonate & anhyd HF at elevated temp (Refs 1 & 3)

Nitrogen Oxyfluoride. See Nitrosyl Fluoride in this Section

Nitrogen Trifluoride, NF₃, mw 71.01; colorless gas or mobile liquid; sp gr 1.537, fr p –206.6°, bp –128.8°. It is one of the Nitrogen Fluorine Compounds. Others are Dinitrogen Tetra-fluoride, Dinitrogen Difluoride and Difluoramino. They are powerful oxidizers suitable for both liquid and solid rocket propelants. Also used for high energy fuels

Nitrogen Trioxyfluoride. See Fluorine Nitrate in this Section

Nitrosyl Fluoride or Nitrogen Oxyfluoride, NOF, mw 49.01, colorless gas; sp gr 1.68
Nitroxy Fluoride or Nitryl Fluoride, NO_2F, mw 65.01, colorless gas; sp gr 2.24 (Air=1), fr p -139°, bp -63.5°; decomp by w., alc & eth. Can be prepd by treating F with 2 moles of NO at liq O temp (Ref 1)
Refs: 1) Gmelin-Kraut Syst Number 5 (1926), 51 2) Lange (1961)

Nitryl Fluoride. See Nitroxy Fluoride

Nitryl Hypofluorite. See Fluorine Nitrate in this Section

Octafluorocyclobutane ("Freon-C318"), (CF_2)_4, mw 200.04; chemically inert dry gas, bp -6°(760mm); high electric strength. Can be prepd by dimerization of tetrafluoroethylene at high temp. Used for electric equipment and as aerosol propellant for foods and pharmaceuticals

Perfluoroethylene or Tetrafluoroethylene. See Ethylene Tetrafluoride in this Vol p E291-L

Peroxydisulfuryl Difluoride, S_2O_6F_2, mw 198.14; colorless liq having extremely unpleasant odor, fr p -55.4°, bp 67.1°; hydrolyzes in water. It ignites org materials immediately upon contact. It can be prepd by reaction of F with an excess of sulfur trioxide at 250° and by combination of fluorine fluorosilicate with sulfur trioxide (Refs 3 & 4)
Refs: 1) Gmelin-Kraut Syst Number 5, Teil B (1963) 2) CondChemDict (1961), not found 3) F.B. Dudley, JChemSoc 1963, 3407-11 & CA 59, 2377 (1963) 4) J.M. Shreeve & G.H. Cady, InorgSynth 7 (1963), 124-28 & CA 61, 269 (1964) 5) Anon., C&EN, Feb 21 (1966), p 40-R, under BRIEFS [During the prepn 500g of S_2O_6F_2 (the method is not indicated), about 200g of fluorine fluorosulfate (SO_3F_2) formed. Sulfuryl fluoride (SO_2F_2) also formed and possibly some unidentified substances. The by-products were distilled into a cold, clean, dry steel cylinder strong enough to withstand press of 135 atm. On warming to RT the cylinder violently exploded]

Phosphorous Pentafluoride, PF_5, mw 125.98, colorless gas, fr p -91.6°, bp -84.8°; d of gas 5.84g/liter; sol in or reacts with w., alcohols, ethers & amines; gas produces a fog in moist air; not corrosive to dry metals or glass, The toxicity is same order as that of BF_3. Phosphorous pentafluoride can be made by treating the chloride with arsenic trifluoride, and by thermal decomp of hexafluorophosphates & the diazonium salts. PF_5 may be converted to PF_3 by heating Cl alone, or with calcium fluoride

Phosphorous Trifluoride, PF_3, mw 87.98; colorless gas, fr p -151.5°, bp -101.8°; d of gas 3.91g/liter & d of liq at bp 1.6g/ml; almost insol in w.; dissolves readily in alkaline solns; much more poisonous than PF_5 & POF_3. Excessive exposure may produce symptoms similar to those of CO. It can be prepd by fluorinating PCl_3 with CaF_2 or with AsF_5 or SbF_5

Polyvinyl Fluoride. See Vinylfluoride Polymer in this Section
Potassium Bifluoride (Potassium Acid Fluoride), $\text{KHF}_2$, mw 78.11; colorless, poisonous & corrosive crystals; mp – decomp; sol in w & dil alc; insol in abs alc. Can be prep'd by crystallizing from anaq soln of KF in HF (Ref 1). Used for etching glass; production of fluorine and of flux in metallurgy


Potassium Borofluoride, Potassium Fluoroborate, or Potassium Fluoroborate, $\text{KBF}_4$, mw 125.92; gritty wh pd (when dried), of gelatinous crystals of weak bitter taste; sp gr 2.5 at 20°, mp decomp 350°; bp – decomp; sl sol in w & hot alc. Prepd by mixing fluoroboric acid with a soln of K hydroxide or carbonate; the resulting gelatinous ppt is washed and dried. Other method is heating of boric acid with K fluosilicate followed by adding K carbonate. Used in grinding wheels, in flux for soldering, in electrochemical processes and in chemical research


Potassium Fluoroborate. See Potassium Borofluoride

Potassium Fluoride: (a) KF, mw 58.10 and (b) KF.2H$_2$O, mw 94.13 (usual commercial form); wh poisonous crystals; sol in w & HF; insol in alc; sp gr 2.48 of (a) & 2.454 of (b); corresponding mp’s 46° & 41°. Can be prep’d by saturating hydrofluoric acid with K carbonate. Used for etching glass, as preservative and insecticide


Potassium Fluosilicate or Potassium Silico-fluoride (Hieratite), $\text{K}_2\text{SiF}_6$, mw 220.29; wh crystals, sp gr about 3.0, mp-decomp; sl sol in w; insol in alc; sol in HCl. Can be prep’d by reacting KCl with fluorsilicic acid. Used for prep’g synthetic mica; in metallurgy of Al & Mg, ceramics & insecticides


Potassium Fluozirconate. See Zirconium Potassium Fluoride in this Section

Rubidium Fluoride, RbF, mw 104.48; wh crystals, sp gr 2.88 at 820°, mp 775°, bp 1410°; v sol in w, sol in dil HF, insol in eth & NH$_3$. Can be prep’d by heating Rb hydroxide or carbonate with HF in a Pt dish and by other methods (Ref 1)


Selenium Tetrafluoride, SeF$_4$, mw 154.96, colorless liquid, sp gr 2.77 at 20°, fp –80°, bp +100°; decompd by w. Can be prep’d by action of F on selenium in a Cu vessel, or by the action of dry Ag fluoride on Se tetra-chloride (Ref 2)

Refs: 1) Gmelin-Kraut, not found 2) Meller 10 (1930), 893 3) Lange (1961), 300

Silicofluoric Acid. See Fluorosilicic Acid in this Section

Silicofluoroform, SiHF$_3$, mw 86.10, colorless gas, sp gr 2.98 at 0°(Air=1), fp –110°, bp –80.2°; dec by w, alc, eth & alkalies; sol in toluene. Can be prep’d by action of AsF$_3$, SnF$_4$ or TiF$_4$ with SiHCl$_3$ (Ref 1)


Silicon Fluoride or Silicon Tetrafluoride, SiF$_4$, mw 104.09; colorless, nonflammable gas with nauseating odor similar to HCl; fumes strongly in air, sp gr 3.57 (Air=1); fp –90°, bp –86°; absorbed in large quantity of w with decomp.; sol in alc, eth &

Silver Fluoride, AgF, mw 126.88, yel or brn crys; sp gr 5.852 at 15.5°, mp 455°, bp 1159°; sol in w, sl sol in NH₃; very hygroscopic; forms hydrate AgF₂H₂O; becomes dark on exposure to light. Can be prepd by heating N. Used in medicine Refs: 1) Gmelin-Kraut Syst Number 61, Teil B (1971), 293 2) Lange (1961), 304 3) CondChemDict (1961), 1022-R; (1971), 787-L 4) Kirk & Othmer 9(1966), 661

Sodium Borofluoride or Sodium Fluoroborate, NaBF₄, mw 109.8; wh crys pdr with bitter taste; sp gr 2.47 at 20°, sp 384° with slow decomp; sol in w, sl sol in alk. Can be prepd by heating NaF & hydrofluoric acid, followed by slow cooling & crysm. Used as fluorinating agent, also in fluxes for nonferrous metals, in electrochem processes and as oxidation inhibitor Refs: 1) Gmelin-Kraut Syst Number 21 (1928), 696 2) Lange (1961), 308 (Fluoroborate) 3) CondChemDict (1961), 1041-R; (1971), 800-R

Sodium Fluoride (Villaumite), NaF, mw 41.99; colorless, poisonous crys, avoid breathing dust; sp gr 2.766, mp 993°, bp 1704°; sol in w; sl sol in alc. Can be prepd by treating Na carbonate with HF. Used for fluorinating of municipal water supply, in insecticides, fungicides, in metallurgy (rimmed steel), electroplating, manuf of glass and vitreous enamels; single crys used as windows in UV & IR radiation detecting systems. May be fatal if swallowed Refs: 1) Gmelin-Kraut Syst Number 21 (1928), 297 2) Lange (1961), 308 3) CondChemDict (1961), 1041-R; (1971), 800-R

Sodium Fluorosilicate or Sodium Silico-fluoride (Salifer), Na₂SiF₆, mw 188.07; wh, odorless, poisonous, granular pdr; sp gr 2.679; mp-decomp at red heat; v sl sol in cold w; better sol in hot w; insol in alc. Can be prepd by neutralization of fluosilicic acid with Na carbonate. Used for fluoridation of drinking w; for manuf opalescent glass, latex foam rubber, metallurgy of Al & Be, insecticide, chem intermediate, etc Refs: 1) Gmelin-Kraut Syst Number 21 (1928), 882 2) Lange (1961), 310 3) CondChemDict (1961), 1042-L; (1971), 801-L

Stannic Fluoride, SnF₄, mw 194.70, wh crys, sp gr 4.78 at 19°/4, mp 705°; v sol in cold w; decomp by hot w. Can be prepd by fluorinating Sn with CIF₃, or by reaction of NOF.3HF x ith metallic Sn in liq phase at 20–120° (Ref 1), and by reacting SnF₂ with F (Ref 3). Used in industrial applications as a catalyst Refs: 1) Gmelin-Kraut Syst Number 46, Teil C (1972), 171 2) Lange (1961), 312 3) Kirk & Othmer 9(1966), 682

Stannous Fluoride or Tin Fluoride, SnF₂, mw 156.72, wh crys, mp 210–215°; bp-decomp in air to SnOF₂; sl sol in w; slowly hydrolyzes. Can be prepd by the dissolution of stannous oxide inaq HF or by dissolving metallic Sn in anhyd or aq HF (Ref 1 & 3). Used in toothpaste as fluoride source Refs: 1) Gmelin-Kraut Syst Number 46, Teil C (1972), 154 2) CondChemDict (1961), 1070-R; (1971), 823-L 3) Kirk & Othmer 9(1966), 682

Strontium Fluoride, SrF₂, mw 125.63; wh pdr, sp gr 4.22, mp 1400°(Lange), 1190°(Ref 2); nearly insol in w; sol in hot HCl. Can be prepd by treating an aq SrCl₂ soln with Na or K fluoride (Ref 1). Used as substitute for other fluorides Refs: 1) Gmelin-Kraut Syst Number 29 (1960), 187 2) CondChemDict (1961), 1080-R; (1971), 829-R
Sulfur Hexafluoride, \( \text{SF}_6 \), mw 146.071 colorless gas; sp gr 5.11 at 20\(^\circ\)C (Air = 1), of liq 1.79 at -39\(^\circ\)C, fr p -50.8\(^\circ\)C (under pressure), bp -83.5\(^\circ\)C; v.sl sol in w; sol in alc, eth & KOH. Prepd by interaction of sulfur & fluorine. Used as dielectric (gaseous insulator for electrical equipment) 

Sulfuric Oxyfluoride or Sulfuryl Fluoride, 
\( \text{SO}_2\text{F}_2 \), mw 102.07, colorless gas, fr p -136.7\(^\circ\)C, bp -55.4\(^\circ\)C; sol in w & alk; insol in conc sulfuric acid. Can be prepd by heating an excess of F & S in a glass tube with \( \text{SF}_6 \) & \( \text{SO}_2\text{F}_2 \) added, or by heating gaseous F & \( \text{SO}_2 \) & \( \text{SO}_2\text{F}_2 \) (Ref 1). Used as insecticide & fumigant

Sulfurous Oxyfluoride, \( \text{SOF}_2 \), mw 86.07, colorless gas, fr p -110\(^\circ\)C, bp -30\(^\circ\)C; sol in benz & ether; decompd by w. Can be prepd by heating F with S in a glass tube and in the presence of the oxyfluoride of sulfur (Ref 1), and by other methods

Tetrafluorodichloroethane. See Dichlorotetrafluoroethane in this Section

Tetrafluoroethylene or Perfluoroethylene.
See Ethylene Tetrafluoride in this Section

Tetrafluorohydrazine or Hydrazine Tetrafluoride, \( \text{F}_2\text{NNF}_2 \), mw 104.02; colorless, mobile liq or gas, bp (calcld) -73\(^\circ\)C; crit temp +36\(^\circ\)C; heat of vaporization 3170cal/mole. Can be prepd by reaction of nitrogen trifluoride with metals at high temp (Ref 3). Ex- plodes in contact with reducing agents. Used as oxidizer in fuels for rockets or missiles; also in org synthesis

Tetrafluoromethane or "Freon-14". See Carbon Tetrafluoride in Vol 2, p C64-L

Thorium Tetrafluoride, \( \text{ThF}_4 \), mw of anhydrous 308.05; wh pdr having approx formula \( \text{ThF}_4 \cdot 1.4\text{H}_2\text{O} \); dehydrated betw 200\(^\circ\)C & 300\(^\circ\)C; mp 1111\(^\circ\)C; reacts above 500\(^\circ\)C with atm moisture to form oxyfluoride \( \text{ThOF}_2 \) and finally the oxide \( \text{ThO}_2 \). Forms a series of compds with other metallic fluorides, such as KF & NaF. Thorium tetrafluoride can be prepd by action of F on thorium chloride or bromide at RT (Ref 1). Used for prepn of Th metal and Mf-Th alloys; also in high temp ceramics
\( \text{ThOF}_2 \) is used as a protective coating on reflective surfaces

Tin Fluoride. See Stannous Fluoride in this Section

Titanium Tetrafluoride, \( \text{TiF}_4 \), mw 123.90; wh pdr, sp gr 2.798 at 20.5\(^\circ\)C, mp (?) , bp 284\(^\circ\)C; sol in w, alc & pyridine; insol in eth. Can be prepd by reacting Ti with \( \text{F}_2 \) at 250\(^\circ\)C or thru reaction of TiCl\(_4\) with anhyd HF. Used in catalytic application and in the formation of adducts

Titanium Trifluoride, \( \text{TiF}_3 \), mw 104.90; viol-red pdr; sp gr 2.98; on heating in air it is transformed slowly to \( \text{TiO}_2 \); sol in cold w; decompd by hot w. Can be prepd by passing HF over heated Ti hydride or by
reacting HF with TiCl₃. Used in catalytic applications.

**Trichlorofluoromethane.** See Fluorotrichloromethane (“Freon-11”) in this Section

**1,1,2-Trichloro-1,2,2-trifluoroethane or Trifluorotrichloroethane (“Freon-113” or “Freon-TF”), FCl₂C₂CClF₂; mw 187.39; colorless, nearly odorless, vol. liq; sp gr 1.576 at 20°, fr p -35°, bp 47.6°, insol in w; miscible with alc, eth & benz. Can be prep from perchloroethylene & hydrofluoric acid. Used as solvent, refrigerant, fire extinguisher and for prep of chlorotrifluoroethylene

**Trifluorochloroethane.** See 1-Chloro-1,2,2-trifluoroethane in this Section

**Trifluorochloroethylene.** See 2-Chloro-1,1,2-trifluoroethylene and its polymer, Fluoroethene, in this Section

**Trifluorochloromethane.** See Chlorotrifluoromethane in this Section

**Trifluorochloromethylbenzenes.** See Chlorobenzotrifluorides in this Section

**Trifluorochlorotoluene.** See under Chlorobenzotrifluorides in this Section

**Trifluoromethane.** See Fluoroform in this Section

**Trifluoromethylbenzene.** See Benzotrifluoride in this Section

**Trifluoronitrosomethane, CF₃NO, mw 99.02;** bright blue, fairly stable gas, very irritant; fr p -150°, bp -84°. Can be prep by inter-action of iodo (or bromo) trifluoromethane with nitric oxide in the presence of UV light. Serves as a monomer for nitroso rubber & as a military poison

**Trifluorotrichloroethane.** See Trichlorotrifuoroethane in this Section

**Tungsten(or Wolfram) Hexafluoride, W F₆, mw 297.86;** colorless gas or l yel liquid; toxic; sp gr (liq) 3.44, fr p 2.5°, bp 19.5°. Can be prep by direct fluorination of powered tungsten, followed by distillation under pressure. Used for vapor phase deposition of tungsten and as fluorinating agent

**Uranium Hexafluoride, UF₆, mw 357.07;** colorless, volatile crystals; sublimes; sp gr 4.68 at 21° (Ref 1), 5.06 at 35° (Ref 2), mp 69.2° at 2 atm (Ref 1), 64.5° at 2 atm (Ref 2); triple p 64.0° at 1134mm (Ref 2); bp 56.2° at 765mm (Ref 1); sol in cold w (Ref 1); reacts vigorously with w, alc, eth and most metals (Ref 2). Obt by fluorination of U tetrafluoride (qv). Used in gas diffusion process for separating isotopes of U

**Uranium Tetrafluoride (Green Salt), UF₄, mw 314.07;** gm, non volatile pd; sp gr 6.70; mp 1000° (Ref 2), 1036° (Ref 3); bp 1417° (Ref 2); insol in w & di acids; sol in conc acids. Prepd by hydrofluorination of UO₂, which, in turn, is obt from fluid bed reduction of higher oxides by hydrogen. Used for prep of U metal and UF₆
Refs: 1) Gmelin-Kraut Syst Number 55 (1936),
Vanadium Pentfluoride, VFs₄, mw 145.95; colorless or yel pd, sp gr 2.177 at 19°, mp 70°, bp 111.2°; sol in w, alc & chl; insol in CS₂. Can be prep by action of F on metallic V or vanadium chloride (Ref 1). Refs: 1) Gmelin-Kraut Syst Number 48, Teil B (1967), 187 2) Lange (1961), 326 3) Sax (1968), 1224-L.


Vinyl Fluoride. See Fluoroethylene in this Section.

Vinylidene Fluoride. See 1,1-Disfluoroethylene in this Section.


Vinylfluoride Polymer (Polyvinyl Fluoride), (-H₂C.CHF–)ₙ. A transparent solid used for prep of films. It possesses superior resistance to chemicals and outdoor weather. The film is flexible, smooth, has high dielectric constant, has low permeability to air & water and has high resistance to heat. This polymer may serve as replacement of paints and as an outdoor protective coating for siding & roof; also for glazing, packaging, and electrical uses. Refs: 1) CondChemDict (1961), 921-R; (1971), 714-R 2) Kirk & Othmer 9 (1966), pp 835–40; "Polyvinyl Fluoride" by L.E. Wolinski.

Zinc Fluoride, ZnF₂, mw 103.38; wh, poisonous pd; sp gr 4.84 at 15°, mp 872°, bp ca 1500°; sol in hot acids, si sol in w, insol in alc. Can be prep by the action of HF on Zn hydroxide or by the addn of NaF to a soln of Zn acetate. Used in ceramic glazes & enamels; impregnating lumber and galvanizing.


Zirconium Fluoride (Zirconium Tetrafluoride), ZrF₄, mw 167.22; wh crys, sp gr 4.43, mp 600° (subl); si sol in cold w; decomp by hot w; sol in HF. Can be prep by treating ZrCl₄ with anhyd HF or by thermal decomp of (NH₄)₄ZrF₄, which can be obt by reacting ZrO₂ with NH₄HF₂ (Refs 1 & 3). Used as a component of molten salts for nuclear reactors. Refs: 1) Gmelin-Kraut Syst Number 42 (1958), 278 2) Lange (1961), 332 3) Kirk & Othmer 9 (1966), 685 4) CondChemDict (1971), 957-R.

Zirconium Potassium Fluoride or Potassium Fluorozirconate, K₂ZrF₆, mw 283.42; wh crys, sp gr 3.58; sol in hot w, insol in NH₄. Can be prep by treating a KF soln with an excess of ZrF₄ soln (Ref 1). Used in prep of metallic Zr.
Flüssige Tri (Ger & Swiss). Liquid TNT. See 2,4,6-Trinitrotoluene under Toluene.

**Fluted Liners.** In the development of shaped-charge projectiles, it became known that spin reduced the penetration capabilities of shell with smooth liners. To obtain better penetration with a spinning charge, so-called fluted liners were developed wherein the exterior surface had ridges emanating from the apex. Initial ballistic tests of such liners made by the rubber-covered-punch process and adapted for assembly into modified 57mm M307A1 HEAT Shell gave promising results. Shells (loaded with Comp B) with these liners were tested by firing from the M18 rifle. These shells, which rotated at about 210rpm, penetrated at least 3 inches in armor-plate in 96% of trials and 6 inches in 40% of trials. When fired at 120rpm in a spin-test app, the average penetration in mild steel was 7.4 inches. The standard 57mm M307A1 HEAT Shell which contains a hemispherical liner cannot be relied upon to penetrate 3 inches of armor plate.

Further development work on liners made by the rubber-covered-punch process was deferred pending evaluation of liners made by the matched-die process when studies indicated that the latter process should produce liners of greater uniformity (Ref 4).

Although the effects of rotation were not known with certainty, it was theorized that when the liner collapses in a rotating shaped charge, the jet formed from the liner also rotates and spreads or splits. To counteract these effects of rotation, tangential components of velocity are necessary. These must be equal in magnitude but opposite in direction to those set up by the initial spin upon all the elements of the liner. The purpose of this counteracting force, called "spin-compensation", is to stop rotation of the jet (Ref 1). Both theory and initial test results indicated that a fluted liner offered the best means of compensating for rotation (Ref 2).

Such a liner was designed in 1946 at the Carnegie Inst of Techn (CIT) and the Nat Bur of Standards (NBS) started work to develop a method for manufg such liners. The rubber-covered punch process is described in Ref 3.

**References:**
1. W.T. August et al., "The Effect of Rotation Upon Shaped Charge Jets", Chap VII, BRL Rep 905, May 1954 (Project TB-3-0134)
3. Staff, Camin Labs Inc, Brooklyn, NY, Progress Reports under Contract No DA1-28-017-ORD-(P)-488

**Fly Cotton.** It consists mostly of dead or unripe cotton fibers from plants which have not reached maturity as a consequence of attacks by parasites, generic factors or lack of nutrient. The fibers collect into tangled masses called "neps". Dead fibers may be recognized in cotton from the fact that they are doubly refractive, showing colors under a polarized microscope. If a mica plate is inserted, the normal (ripe) fibers remain bright in all positions, while the dead fibers show black and white portions (according to their direction)

Unripe fibers show less contrast than dead ones under the polarized microscope with mica plate. The unripe fibers are of about the same width as the normal fibers but are not twisted, while "dead" fibers are broad and flat.

Both dead and unripe fibers are not suitable for nitration because they produce unstable NC.

**References:**
1. Marshall 1917, 167
2. Ibid, 2 (1917), 696
3. Ibid (1932), 33
**Flying Spot Microscope.** A television-type scanner illuminates specimen in compound microscope to obtain pictures superior in size, brightness, contrast & resolution to those of normal microscope. Discrete particles are automatically counted and sized.


**FNH Propellants.** Flashless-nonhygroscopic propellants were developed after WWI in the US by incorporating into ordinary smokeless propellant ingredients such as DNT, TNT, DPhA, DBuH, hydrocellulose, etc (See Table F8)

327 4) Orhirt (1946), 26–7 5) Fedoroff & Clift 4 (1946), 36

**Foamed Explosives for Floating Mine.** An invention by Stark (Ref 1) provides a floating mine which consists of an expl having a closed-cell foam structure of greater and more shattering effect than the same wt of high-density expl. Buoyancies of these expls are of 20 to 50 lbs per cu ft. The foamed expls consists of HE's (such as TNT, NC, PETN or RDX) bonded by a thermostetting resin.

*Ref:* H.J. Stark, USP 2845025 (1958) & Ordn 43, 662 (Jan-Feb 1959)

### Table F8

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<tr>
<th>Ingredients</th>
<th>Single-Base Propellants</th>
<th>Double-Base Propellant</th>
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<td>Formulation 2</td>
</tr>
<tr>
<td>NC (12.6% N)</td>
<td>74</td>
<td>} 85</td>
</tr>
<tr>
<td>NC (13.25% N)</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>NC (13.5% N)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>NG</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>DNT</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>TNT</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>DBuPh</td>
<td>–</td>
<td>5</td>
</tr>
<tr>
<td>DPhA</td>
<td>1</td>
<td>1(added)</td>
</tr>
<tr>
<td>Hydrocellulose</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

The term "flashless" is relative and depends on the caliber of the weapon in which it is used and, therefore, on the size of the charge. The compositions given above are nearly flashless propellants for small-caliber guns, incl 75mm, but they would not be flashless in larger guns. For these it is necessary to add either more coolants, such as DBuPh or about 1% or more K sulfate or other salts (See also Cannon Propellant, p C29 in Vol 2 of Encycl and Flash Reducing Agents in this Vol).

*RefS:* 1) D.R. Cameron, PATR 10 (1931)
2) Hayes (1938), 8, 14 3) Davis (1943)

**Foams.** See under Emulsification, Emulsion, Foaming and Foam in Vol 5, p E87-R


**FOBS** (Fractional Orbital Aerospace Bombardment System). A statement by Secretary of Defense, Robert S. McNamara, to the press on 3 November 1967 acknowledging the development by the Soviets of a FOBS. McNamara claimed in his pronouncement that FOBS posed no critical new threat.

*RefS:* 1) Time, Vol 90, No 19, p 25 (10 Nov 1967) 2) Staff, Ordn 52, 354 (Jan-Feb 1968)
Fog. Any heterogeneous suspension of droplets of water or other liquid substances in a gas which disturbs its transparency may be called a fog. If the particles in suspension are solid, the fog is usually called smoke or "smog". In Chemical Warfare Service, the term "Smoke" is used for both liquid and solid suspensions
Refs: 1) Hackh’s Dict (1944), 349 2) Vol 2 of Encycl, "CHEMICAL AGENTS", pp C165-R to C171-R

Fog Acid (Nebelsäure in Ger). A smoke-screen agent consisting of 50/50-Chlorosulfonic acid/Sulfur trioxide (by weight)

Fog Point. The temperature at the point when a clear liquid becomes opaque is called the fog point
Refs: R.D. Miller, Analyst 74, 652 (1949)

Fog Signals. See under Signals

Föhn Gerät or RZ Föhn (RZ 73 Flight). A 73mm air-to-air missile developed in 1941 by converting a Ger Army rocket. It used solid propellant and could be considered as predecessor of R-4/M. This was a 2-inch solid propellant rocket which carried about 1 pound of HE and had tail surfaces which could be folded back. It was mass-produced towards the end of WWII at the Deutsche Waffen- und Munitionsfabriken at Lübeck. As many as 48 of these missiles could be carried on the underwing racks of a fighter plane and fired practically simultaneously against a bomber formation at a range of 1200 to 1500 yards. It was claimed that a single hit with such a rocket was sufficient to bring down a bomber (Ref 1)

Acctg to Gatland (Ref 2), missile R4/M had diam 2.16 inches, overall length 2.75 ft, launching weight 7.75 lbs, and range 0.5 mile. It used a singular tabular grain propellant which had a burning time of 0.8 sec

Folded Head Ammunition. One of the earlier American "center-fire" systems, used from about late sixties to about eighties of the last century. It consisted of straight cylindrical copper cartridge, which looked on the outside like the present "rim-fire" cartridge. As a primer it had a copper cup (contg some fulminating mixture) of diam slightly smaller than the inside of cartridge. The end of the cartridge and

Folded Head Cartridge. See Vol 4, p D756-L

Folding Skirt Projectile (Tapered Bore). This type of projectile is fired thru a tapered bore which may be either built into the gun or added to a std gun by a special muzzle attachment. The taper serves toswagen down the flanged skirts which extend from the main body of proj as a jacket. As a result the emergent caliber is much less than the original diam. In this way, the accelerating pressure of the powd gases acts on a large area in the gun bore, while a small (emergent) area is presented to the resisting pressure caused
Follow-Through Projectile for Shaped Charges.

The present method of obtaining efficiency from a shaped charge is to have the length of the explosive behind the cavity liner equal to two or three times the diam of the cavity liner. Using this method, any follow-through projectile must be placed behind the point of deton. No successful proj of this type has yet been presented because of the difficulty of causing the proj to travel thru the deton products and enter the hole in target where jet penetrated. The object of this invention is to increase the efficiency of shaped charges by introducing a follow-thru proj or erosive agent in the jet hole formed by the charge.

In the follow-thru proj (See Fig), the deto of the expl causes the deto wave to pass around the inert core and to impact with the liner which sends out a narrow jet, piercing the target. In the meantime, the propint behind the follow-thru proj has burned, propelling the proj thru the jet hole to explode inside the target.

Ref: S.A. Moses, USP 2809585 (1957) & Ordn 43, 130 (July-Aug 1958)

Fonberg Effect. See Fonberg Phenomenon

Fonberg Phenomenon. Z. Fonberg (Ref 1) observed that the deto of shaped charges of certain nitrocompds with lined cavity is accompanied by the appearance of electromagnetic radiation which seems to be of such intensity that evidence of nuclear transmutation has been observed. These experiments of Fonberg were repeated at la Poudrière de Vonges (France) and described by Tausin (Ref 2). No definite conclusion can be drawn from these investigations and further work is required if it is desirable to know whether the phenomenon is due to transmutation, or other cause.


Fonckite V. A mining expl which contd:
Amm Perchlorate 53.24, Amm Oxalate 32.30 & TNaphthalene 14.46%  
Ref: Gody (1907), 712
Fonction de progressivité expérimentale
(Fr. for Function of Experimental Progressivity). In order to determine the so-called "vivacité expérimentale des poudres" (experimental quickness of propellants) from the data obtained when propellants are fired in a manometric bomb, it is necessary first to determine the so-called "fonction de progressivité". For description of this function, see the following publications:
1) J. Dupuis, MAF 17, 799-830 (1938) (Note on the laws of combustion of propellants)
2) J. Dupuis & M. Calvet, MAF 18, 37-66 (1939) (Tests in the Dupep-Schmidt bomb)
3) M. Prache, MP 32, 343-375 (1950) (Contribution to the study of the "fonction de progressivité expérimentale des poudres" on firing in a manometric bomb; application to the examination of surface-treated propellants

Fontaine Powders. These powders were fabricated by Fontaine before 1869 right in the center of city of Paris, near Sorbonne. They contained Potassium Picrate and Potassium Chlorate and were used for a while for filling shells and torpedoes. They were very powerful and superior to Designolle powders. However, they were very sensitive and their manufacture was stopped after a disastrous explosion occurred in 1869 at the plant, killing five workers (1892)
Refs: 1) Cundell (1889) in MP 5, 336 (1892)
2) Daniel (1902), 616 (Under Picrates)
3) Clift & Fedoroff (1943), p F2 4) Guia, Trattato VI(1), (1959), 397

Fontana, Barelli & de Choisy Powder.
Military and sporting propellants proposed in 1869: a) K chlorate 70.4 & red lead 29.6%
b) K ferrocyanic 42.5, sugar 29.3, carbon 13.2, K permanganate 8.8, hydrocarbon 2.9, licopodium 1.7 & powdered gum 1.5%
Ref: Giua, Trattato VI(1) (1959), 392

Fontana, Nicola (called Tartaglia) (1500-1557). An Italian scientist, the creator of theory of artillery. The word "artillery" was first used by him, deriving it probably from "arte de tirare"
Ref: 1) A.D. Blinov, KursArtillerii, Voyannoye Izdatel'stvo, Moscow, V 1 (1948)

Forbidden Explosives. According to Sec 73.51 of ICC’s (Interstate Commerce Commission’s) Regulations, the offering of the following explosives for transportation by common carriers by rail freight, rail express, highways, or water is forbidden:
1) Explosive compns that ignite spontaneously or undergo marked decomp when subjected for 48 consecutive hrs to a temp of 75°F (167°C)
2) Explo compns conng an Amm salt and a chlorate
3) Liquid NG, DEGDN or other liq expls not defined as acceptable expls
4) Expls condemned by the Bureau of Explosives
5) Leaking or damaged packages of expls
6) Condemned or leaking Dynamite unless it was repacked by a competent person in the presence of, or with the written consent of, an inspector, or with the written authority of the Chief Inspector of the Bureau of Explosives
7) Firecrackers, flash crackers, or salutes, the explosive content of which exceeds 12 grains in weight each, or pest control bombs, the expl content of which exceeds 18 grains each in weight
8) Fireworks that combine an explosive and a detonator or blasting cap
9) Fireworks conng an Amm salt and a chlorate
10) Fireworks conng yellow or white phosphorus
11) Fireworks or fireworks compns which behave as described in (1)
12) Fireworks condemned by the Bureau of Explosives, except when properly re-packed as samples for lab examinations
13) Toy torpedoes, the maximum outside dimension of which exceeds 7/8 inch, or toy torpedoes conng a mixture of K chlorate, black antimony and sulfur, with an average wt of mixture in each torpedo exceeding 4 grains
14) Toy torpedoes contg a cap composed of a mixture of red phosphorus and K chlorate exceeding an average of 0.5 grains per cap
15) Fireworks contg Cu sulfate and a chlorate
16) New expls (except samples for lab examination) until approved for transporta-
tion by the Bureau of Explosives
17) Loaded firearms
Re/fs: 1) Agent H.A. Campbell's Tariff No 10, "Interstate Commerce Commission Regulations for Transportation of Explosives and Other Dangerous Articles by Land and Water", 30 Vesey St., New York 7, NY (1957) 2) R.M. Gaziano’s Tariff No 27, "Hazardous Materials Regulations of the Department of Transporta-
tion", Association of American Railroads, Washington, DC 20036

**Force and Covolume of Colloidal Propellants.**
Pressure-density of loading relationships were de
d in France for various chem compns and grain forms. Suitable corrections were made for
cooling effects by the walls of bombs. The data were used as a basis for calculating force and covolume. Theory and exptl values agreed satisfactorily
Re/fs: H. Marmour & G. Aunis, MAF 22, 133–70 (1948) & CA 44, 8659 (1950)

**Force and Impetus in Detonation.** See Vol 4, pp D391-R & D393-L under Detonation (and Explosio-

**Force Brisante.** Fr for Bursting Power

**Force Constant.** The decompn of a unit mass of propn always liberates the same
amt of energy which then heats the product gases to the same temp independent of density. For most propnts, the most important equili-
brium is the water gas equilibrium and, since this is equimolar, the assumed equation of
state is sufficiently accurate for use in the interior ballistic of guns
It is std practice in the formulation of interior ballistic theory to assume an equation of state of the simple covolume type. For a
gas obeying the Abel equation of state, the internal energy depends only on temp and not on density. It is expressed as

\[ P (V - \eta) = nRT \]

In interior ballistics it is usually written in terms of a unit wt of gas, so that \( V \) & \( \eta \) have dimensions vol per unit wt, and \( n \) is the
number of moles per unit wt. Many authors also define \( R \) as the gas constant per unit
wt so that \( n \) does not appear explicitly in the equation. \( R \) so defined is not constant unless \( n \) is also constant
If \( T_0 \) is the adiabatic flame temp, the energy released by the decompn of unit wt of propnt, called "Force Constant", is defined by

\[ F = nRT_0 \]
This force can be determined experimentally by buming a chge of propnt in a closed chamber and measuring the max pressure pro-
duced and using Abel's equation (above), along with suitable cooling corrections. This requires a knowledge of \( \eta \) which can be detd
simultaneously by firing a series of chges of different masses and measuring the corre-
sponding pressures.

The table includes values of the force for a number of std & experimental gun propnts. Force & other thermodynamic parameters of propnts can be calculated theoretically if the necessary thermochemical data are available. Results of such calculations are given in Ref 2
### Table F8a

**Calculated Thermochemical Values for US Propellants**

<table>
<thead>
<tr>
<th>Propellant (Use)</th>
<th>Specification Number</th>
<th>Isochoric Flame Temp, °K</th>
<th>Gas Volume moles/g</th>
<th>Force ft lbs/lb x 10⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMR Small Arms</td>
<td>JAN-P-733</td>
<td>2417</td>
<td>0.0453</td>
<td>305</td>
</tr>
<tr>
<td>M1 Artillery</td>
<td>JAN-P-309</td>
<td>3319</td>
<td>0.0390</td>
<td>360</td>
</tr>
<tr>
<td>M2 Artillery</td>
<td>JAN-P-323</td>
<td>3245</td>
<td>0.0394</td>
<td>355</td>
</tr>
<tr>
<td>M5 Artillery</td>
<td>JAN-P-323</td>
<td>2570</td>
<td>0.0443</td>
<td>317</td>
</tr>
<tr>
<td>M6 Artillery</td>
<td>JAN-P-309</td>
<td>3734</td>
<td>0.0354</td>
<td>368</td>
</tr>
<tr>
<td>M7 Mortar</td>
<td>JAN-P-659</td>
<td>3695</td>
<td>0.0371</td>
<td>382</td>
</tr>
<tr>
<td>M8 Mortar</td>
<td>JAN-P-381</td>
<td>3479</td>
<td>0.0362</td>
<td>382</td>
</tr>
<tr>
<td>M9 Mortar</td>
<td>JAN-P-20306</td>
<td>3000</td>
<td>0.0407</td>
<td>339</td>
</tr>
<tr>
<td>M10 Recoilless</td>
<td>PA-PD-123</td>
<td>2996</td>
<td>0.0404</td>
<td>336</td>
</tr>
<tr>
<td>M12 Small Arms</td>
<td>JAN-P-528</td>
<td>2710</td>
<td>0.0434</td>
<td>327</td>
</tr>
<tr>
<td>M14 Artillery</td>
<td>JAN-P-309</td>
<td>2594</td>
<td>0.0465</td>
<td>336</td>
</tr>
<tr>
<td>M15 Artillery</td>
<td>PA-PD-26</td>
<td>3017</td>
<td>0.0434</td>
<td>364</td>
</tr>
<tr>
<td>M17 Artillery</td>
<td>PA-PD-26</td>
<td>2577</td>
<td>0.0422</td>
<td>319</td>
</tr>
<tr>
<td>M18 Small Arms</td>
<td>PA-PD-26A</td>
<td>2938</td>
<td>0.0448</td>
<td>346</td>
</tr>
<tr>
<td>T18 Recoilless</td>
<td>PA-PD-329</td>
<td>3071</td>
<td>0.0413</td>
<td>353</td>
</tr>
<tr>
<td>T20 Artillery</td>
<td></td>
<td>2388</td>
<td>0.0479</td>
<td>314</td>
</tr>
<tr>
<td>T25 Recoilless</td>
<td>PA-PD-329</td>
<td>3081</td>
<td>0.0416</td>
<td>356</td>
</tr>
</tbody>
</table>

**Force de l’explosif (Force spécifique, ou Force théorique) de Sarau**, also called Force, Pression spécifique (Fr for Force of an Explosive). This is an arbitrary value proposed by Sarau for the estimation of the performance of explosives. The value may be calculated from the equation given in Marshall 2(1917), p 467, as follows:

\[
 f = \frac{v_o Q}{C} + \frac{p_0 V_o T_1}{273}
\]

where:

- \( f \) = "force" expressed in kg/sq cm exerted by the expln of 1 kg in 1 liter
- \( v = \) volume of the vessel in which the expln takes place
- \( Q = \) quantity of heat set free by the expl of unit weight
- \( v_o = \) "specific volume" of the gaseous products from a unit weight of expl calculated to 0°C and standard pressure, \( p_0 \)
- \( C = \) sum of the mean specific heats of the products at the temp of expln. It is a very uncertain quantity
- \( T_1 = \) the absolute temperature of the expln before it is fired

Pepin Lehalleur (1935), p 41, gives the following simplified formula:

\[
 f = \frac{p_o V_o T}{273.1}
\]
where:

\[ p_0 = \text{atmospheric pressure equal to } 1.0333 \text{ kg/sq cm} \]

\[ V_0 = \text{volume of gases developed on expl in liters per kg \& calculated at } 0^\circ \text{ and } 760 \text{ mm, with water as vapor} \]

\[ T = \text{absolute temperature developed on expln} \]

The following values for \( f \) are given by

Pepin Léhauser (1925), pp 49, 54 & 78:

TNT 8910 & 8080; PA 9850 & 8950; 92/8
Blasting Gelatin 12300; PETN 12700; RDX 12619 & 12600; Tetryl 10800; NC (13% N)
10730; MF 5630; LA 4339; NG 7450; Nitrogen Sulfide 6479; Black Powder 2810; \( \text{NH}_4\text{NO}_3 \)
5575; \( \text{NH}_4\text{ClO}_4 \) 4860 in kg/sq cm

The force \( (f) \) was used by Kast in his formula for the theoretical deton of brisance \( (B) \), called "pouvoir brisant" in French:

\[ B = f dD \]

where:

\[ d = \text{density of an expl \&} \]
\[ D = \text{velocity of det} \]

[See also Vennin, Burlot & Lécorché (1932), p 53 and H. Murasor, MAF 22, 133–70 (1948), La force et le volume des poudres colloidales.]

In the paper of R. H. Kent, J Appl Phys 13, 348–54 (1942), the following definition of Force was given on p 349:

"Force of an explosive is roughly an index of the weight lifting or heating ability. Suppose the explosion takes place in a large closed chamber with rigid walls. If \( v \) is the volume of the chamber and \( p \) is the pressure produced by explosive gases as they fill the chamber, the "force" can be defined as the product of \( v \) and \( p \) per unit wt of expl. If the chamber volume is sufficiently large to permit the perfect gas law to hold (approximately), the product \( p v \) is practically independent of the volume for a given expl. If an expl detonates in a confined space, this definition is no longer valid, since the density is so high that the perfect gas law is no longer a good approximation. For such cases, one takes the force as proportional to the product of the number of the gram-molecules per gram of expl and the temperature. It is evident that if the density is small, this definition of force is equivalent to the one given above.

The forces of a number of expls were detd experimentally when they deflagrated or burned, but no reliable direct measurements of forces produced on detonation have been obt. However, it is possible to calculate the forces from thermo-chemical data. Some of these data were obt by an analysis of the band spectra of the various molecules concerned by quantum-mechanical methods, which permitted one to calculate the specific heats and equilibrium constants as functions of the temperature. Others obt by direct measurements of the heats of formation of the various substances from their elements. The results obt by these methods for deflagrating and burning expls agreed fairly closely with the forces as obt by direct measurements.

In making the above mentioned calculations for explosives, it is convenient to assume some pressure in the explosion since theory and experiment both indicate that the compn of the products of expln depends upon the pressure. For example, a very high pressure will tend to produce solid carbon or smoke. It is for this reason that a cloud of black smoke produced on expln of a charge of TNT indicates that high pressure occurred and that, therefore, the charge detonated and did not merely deflagrate or burn (which would produce a relatively low pressure).

The following forces, in inch lb/lb calcd at 1500000 psi (100000 atm), listed by Kent are shown here in Table F9: TNT 3627000, Tetryl 4728000, Picric Acid 3999000 and Blasting Gelatin 4974000.

It was mentioned that on deton of TNT

<table>
<thead>
<tr>
<th>Explosive</th>
<th>CO₂</th>
<th>CO</th>
<th>H₂O</th>
<th>H₂</th>
<th>N₂</th>
<th>OH</th>
<th>NO</th>
<th>O₂</th>
<th>O</th>
<th>C</th>
<th>CH₄</th>
<th>NH₃</th>
<th>HCN</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT</td>
<td>7.3</td>
<td>59.7</td>
<td>3.2</td>
<td>0.7</td>
<td>16.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.7</td>
<td>3.5</td>
<td>1.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Tetryl</td>
<td>8.4</td>
<td>59.8</td>
<td>4.8</td>
<td>0.8</td>
<td>22.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>1.2</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Picric Acid</td>
<td>12.5</td>
<td>63.1</td>
<td>4.3</td>
<td>0.5</td>
<td>17.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>0.7</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Blasting Gelatin</td>
<td>49.4</td>
<td>7.5</td>
<td>18.5</td>
<td>0.1</td>
<td>16.8</td>
<td>2.2</td>
<td>2.7</td>
<td>2.7</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table F9

Percentage Products (by Weight) of Explosion (or Detonation) for the Following Explosives
there was produced a large amt of smoke. Actually, the gas produced on expln of TNT contd 5.7% carbon by weight, as can be seen from Table F9 giving values calcd by Kent using equilibrium constants given by B. Lewis & G. von Elbe in JACS 57, 612 (1933).

Since the term pressure (p) developed on deton or expln is in the formula for calculating the force, we are including its description as given in the paper of Kent, p 352. Due to the fact that such pressures are enormous, no experimental procedure for direct measuring them is known. Although these pressures have not been directly measured, there is a certain phenomenon accompanying a detonation which enables one to assign at least an approx lower limit of the pressure developed.

It is known that at low pressure and high temperature all the carbon would unite with oxygen and hydrogen and there would be no smoke. In this case the total volume (v) of gases will be greater than if the smoke were produced, which happens at high pressures. From the knowledge of thermochemical data, one can compute approx the pressure at which the smoke begins to form for various expls or proplnts. For example, it has been calcd that the smoke forming pressure for NC is 1100000psi.

Another important characteristic of an explosive, which might influence the force is the density, abbrd as d. This is especially important in underwater explosions, such as of sea mines, torpedoes, depth bombs and bombs dropped alongside a ship. If the volume in which the expln occurs is large, compared with the vol of the expl itself, the free space available for the motion of the molecules of the expl gas, is large compared with the molecules themselves. Under these conditions, the perfect gas law holds approximately, that is the product of pressure and volume (pv) is approx constant and is approx independent of v. It follows that under these conditions with a given amt of explosive, the pressure is approx proportional to 1/v.

Consider now an explosion taking place in a confined space, such as that of a bomb under water. Under these conditions, the volume occupied by the gaseous molecules is no longer small compared with the total vol available and the perfect gas law no longer holds. However, the previous statement holds if a new definition of v is given, namely if it is taken not as total volume, but as the "free volume" available for the motion of the molecules. Since the space taken up by the molecules is approx proportional to their number and since the number for ordinary explosives is approx proportional to their weight, it follows that the space occupied by the molecules themselves is approx proportional to the wt of the explosive.

Consider further that two bombs of the same size are exploding under water. The bombs are filled with two different explosives, having the same force as measured in inch lb/lb, but having different densities. Assume that the expl of No 2 has twice the density of that of bomb No 1 and thus its weight will be twice as great. Since the force per pound is the same, the total force of bomb No 2 will be twice as great as that of bomb No 1. In addition, the denser explosive will, in general, have more molecules than the other and these will occupy more space. Since the pressure varies inversely as the free space (which is the total space minus the space effectively occupied by the molecules) the pressure produced by the denser explosive should be considerably higher than twice that produced by the less dense expl.

In certain applications, especially in submarine work, the magnitude of the pressure obtainable should be of great importance, hence the desirability of high density.

Following are maximum loading densities for some expls: NG 1.60, Blasting Gelatin 1.63, TNT 1.55 (average d cast in shell), Tetryl 1.65 & PA 1.69 (Kent, p 351).

Another important characteristic of an explosive which might influence its force is the energy, which is defined as the heat (in calories per unit weight) produced on detonation or explosion. It may be either calculated or determined experimentally using a small, thick-walled calorimetric bomb. When a charge of an expl first detonates the gases produced are at very high pressure,
but they are moving at a relatively low velocity. As the gases immediately begin to expand, the heat energy is converted in part into kinetic energy of motion of the gas, while another part is used in pushing aside the atmosphere. At a short distance from the point of expln, the pressure in the expanding gases is very much reduced, but the envelope has attained a velocity of the order of 10000 to 15000 ft/sec. A gas of high density moving at very high velocity is very destructive.

The following values for energy in cal/g are given by Kent (p 352): TNT 782, PA 830, Tetryl 988 and Blasting Gelatin 1364.

When a bomb is dropped inside a building, the most important characteristic of the expln from a military point of view is probably the force. For a bomb of a given weight, the outward thrust on the walls depends mainly on the force. If on the other hand the bomb is dropped in the open alongside a ship or a building, the effect produced would depend not only on the force but also on the rapidity with which the explosion takes place and this is determed by its rate of detonation, abbreviated as D (Kent, p 350).

This destructive effect depends also on the ability of an explo to produce damaging blast effect, which is caused mainly by exploding gases which attained high velocities in the vicinity of the point of expln. Since this requires heat of high temperatures, it is a plausible assumption that blast effect is proportional to the energy. On this basis the relative blast effect of several expls, with TNT taken as unity, was given by Kent on p 352: TNT 1.00, PA 1.06, Tetryl 1.26 and Blasting Gelatin 1.74.

It must be noted that for closely confined expls, the force (F), the rate of deton (D) and density (d) are all of great importance. In order to obtain a means for rating confined expls, all these factors must be taken into consideration. This was done by Kast, who proposed calling the product of these values brisance or shattering effect and designated it as B (See the beginning of this item and in Vol 2 of Encycl, p B265-R).

The comparative brisance by Kast,

\[ B = fD, \] as given by Kent on p 352 is:

TNT 1.00, PA 1.23, Tetryl 1.47 & Blasting Gelatin 1.59.

**Force or Impetus.** See Vol 4, p D391-R under Detonation (and Explosion) Impetus and Available Energy

**Force de pénétration.** Fr for Penetrating or Perforating Power

**Forcement dans les bouches à feu.** Fr for Forcing in Gun Barrels, which will be described under Résistances passives et forcement dans les bouches à feu (Fr for Passive Resistances and Forcing in Gun Barrels)

**Force propulsive.** Fr for Propelling Force

**Force spécifique.** Fr for Specific Force

**Forcîte américaine.** See under FORCITES

**Forcîte antigrisouteuse.** See under FORCITES

**Forcîte extra.** See under FORCITES

**Forcîte Gelatine.** See under FORCITES

**Forcîte de Lewin.** See under FORCITES

**Forcîte supérieure.** See under FORCITES

**FORCITES.** Acdng to Daniel (Ref 1) and Giua (Ref 9), Forcites are Gelatin Dynamites patented in 1880 by Swedish Officer Lewin.
Gody (Ref 2, p 374) describes under the title Forcite de Lewin or Forcite supérieure the compns contg NG 65–75, "cellulose acétique" 4, dextrine 4 & poudre de mine (BPdr) 30–20%. "Cellulose acétique" was prep’d by treating cotton linters with a mixture of Na acetate and sulfitic acid, followed by washing with a large quantity of water, pulping to the size of fibers used in the manuf of paper, and drying. The resulting acetate was partly sol in NG forming a liquid jelly. Lewin also prep’d Forcite n° 1 which contd 48% NG, Forcite n° 2 with 30% NG and Forcite n° 3 with 20–25% NG (Ref 2, p 374). Under the title of Forcite américaine, Gody (Ref 2, p 375) gave the following: NG 7.9–70, NC 0.1–4.0 & absorbent 92–20%. Compn of the absorbent was NaN₃ 84.1, sulfur 9.5, colophony 3.7 & wood tar 2.7%. Accdg to Thorpe (Ref 4 as quoted in Ref 7), Forcites are plastic expls invented in the USA in 1881, and that one of the best compns contained NG 75, CC (Collodion Cotton) 7 & K nitrate 18%. Dextrine or pulped cotton could replace part of the CC. Another Amer Forcite was known as Forcite Gelatin. It consisted of NG 95–96 & soluble NC 5–4% (Ref 8, p 36). Forcites were manufd in Belgium at the Baelen-sur-Nèthe, and Gody gives on p 374 eight compns manufd there. Marshall (Ref 3), Naoûm (Ref 5) and Davis (Ref 6) list only seven of the Gody’s eight compns (See the table), omitting another Extra which contained NG 74, NC 6, dried woodflour 5.5, KNO₃ 14 & MgCO₃ 0.5%

<table>
<thead>
<tr>
<th>Components</th>
<th>Extra</th>
<th>Supérieure</th>
<th>Supérieure F</th>
<th>No 1</th>
<th>No 1P</th>
<th>No 2</th>
<th>No 2P</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>49</td>
<td>49</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>NC</td>
<td>3.5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>NaN₃</td>
<td>–</td>
<td>24</td>
<td>–</td>
<td>36</td>
<td>–</td>
<td>35</td>
<td>–</td>
</tr>
<tr>
<td>KNO₃</td>
<td>–</td>
<td>–</td>
<td>23</td>
<td>–</td>
<td>37</td>
<td>–</td>
<td>46</td>
</tr>
<tr>
<td>AN</td>
<td>25</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Woodmeal</td>
<td>6.5</td>
<td>8</td>
<td>9</td>
<td>13</td>
<td>11</td>
<td>11</td>
<td>–</td>
</tr>
<tr>
<td>Bran</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>MgCO₃</td>
<td>1</td>
<td>1</td>
<td>1 (added)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: Forcite Extra is actually an Ammonia Gelatin Dynamite. The same Forcites as above are listed by Giua (Ref 9) as French Forcites. Gody also lists on pp 702, 706 & 715 the following Forcites antigrisouteuses (See Table F11)
Table F11
Forcites antigrisoueuses

<table>
<thead>
<tr>
<th>Components</th>
<th>n° 1a</th>
<th>n° 2</th>
<th>n° 3a</th>
</tr>
</thead>
<tbody>
<tr>
<td>de Baalen-sur-Néthe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AN</td>
<td>70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NG</td>
<td>29.4</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td>CC</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MgSO₄</td>
<td>-</td>
<td>44</td>
<td>-</td>
</tr>
<tr>
<td>Cellulose</td>
<td>-</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>KNO₃</td>
<td>-</td>
<td>-</td>
<td>34</td>
</tr>
<tr>
<td>Ba(NO₃)₂</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>-</td>
<td>-</td>
<td>38.5</td>
</tr>
<tr>
<td>Bark flour</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Na₂CO₃</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
</tbody>
</table>

a = Compn of n° 1 adds to 100.4%, while that of n° 3 adds to 101%

Rejs: 1) Daniel (1902), 302–304 2) Gody (1907), 374, 375, 702, 706 & 715
(Table) 6) Davis (1943), 346 7) Clift & Fedoroff 2(1943), pp F2 & F3 8) Fedoroff & Clift 4(1946), 36 9) Giua, Trattato VI(1)(1959), 344 (Table)

Fédrit (Get). Permissible Gelatin Dynamites exist in several formulations, such as shown in Table F12

Table F12

<table>
<thead>
<tr>
<th>Component</th>
<th>Fédrit</th>
<th>Fédrit I</th>
<th>Fédrit IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>41.0</td>
<td>37.0</td>
<td>38.0</td>
</tr>
<tr>
<td>NG</td>
<td>23.0</td>
<td>25.5</td>
<td>21.0</td>
</tr>
<tr>
<td>CC</td>
<td>1.0</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>MNT</td>
<td>3.5</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Glycerin</td>
<td>8.7</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Cereal or potato flour</td>
<td>-</td>
<td>-</td>
<td>12.0</td>
</tr>
<tr>
<td>KCl</td>
<td>22.0</td>
<td>24.0</td>
<td>19.0</td>
</tr>
<tr>
<td>China clay</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ammon oxalate</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Dextrine</td>
<td>0.7</td>
<td>4.0</td>
<td>-</td>
</tr>
</tbody>
</table>


3) Fedoroff et al, PATR 2510 (1958), p Ger 52-L

Foreign Ammunition and Weapons. See under specific ammunition or weapon item, eg, bombs or specific country, eg Belgian, British

Foreign Artillery Fuzes of WWII. See Vol 4, pp D923 to D925

Foreign Bomb Fuzes of WWII. See Vol 4, p D1008 to D1010

Foreign Cannon Propellants. See Vol 2, p C37-L

Foreign Commercial (Industrial) Explosives. See Vol 3, pp C437 to C444 (For Non-permissible) and pp C444 to C459 (For Permissible)


Forensic Chemistry (Chemical Criminalistics). This branch of science relates to the application of chemical knowledge and techniques to the study of physical evidence connected with crime. Investigation of firearms, ammunition and expls is one of the duties of a forensic chemist

Formaldehyde (Monomeric Formaldehyde, Methanol, Formic Aldehyde, Formalin or Formol), HCHO or CH₂O; mw 30.03, d 0.815 at -20 °C, vapor d 1.067 (air = 1.0); fr p -119 °C (Walker and Faith et al); bp -19 °C (Walker and Faith et al); ignition temp 572 °F; explosive limits (% by volume of air), lower 7, upper 73.

Colorless gas with suffocating, pungent odor. The product known in commerce is its 37% aqueous solution. It is poisonous. Formaldehyde was first prep'd in 1859 by A.M. Butlerov by hydrolyzing methylene acetate previously obtained by the reaction of methylene iodide with silver acetate. A.F. Hofmann, in 1868, prep'd formaldehyde by passing a mixture of methanol vapors and air over a heated platinum spiral, serving as a catalyst. The following reaction takes place: \[\text{CH}_3\text{OH} + \frac{1}{2}\text{O}_2 (\text{air}) \rightarrow \text{CH}_2\text{O} + \text{H}_2\text{O}\]. The present method of preparation is essentially the same as used by Hofmann, except that cheaper catalysts than platinum are used, such as Ag and Cu in multilayer gauzes or screens, vanadium and molybdenum oxides, iron oxides or other metal oxides. Limited amounts of formaldehyde are also prep'd by the oxidation of natural gas and the lower petroleum hydrocarbons.

All of these methods are described by Walker (Ref 2) and Faith, Keyes & Clark (Ref 3).

Procedure. Briefly the present method of manufacture by the methanol process is as follows:

Air is drawn thru methanol at such a rate that a mixture containing 30-50% methanol is obt'd. The alcohol-air mixture passes thru a preheater (100-300 °C) in order to eliminate any alcohol in liquid form, and then goes to the reactor, where it remains only 0.01 second. The reactor contains either Ag or Cu multilayer gauze or screen, maintained at 450-600 °C. The resulting gaseous product is absorbed in water to give the commercial product.

When metallic oxides are used as catalysts, a large excess of air is required — 5 to 10 times that required by the metallic catalysts.

Although other methods of preparation, involving the hydrogenation of carbon oxides, the pyrolytic decomposition of formates etc., have been patented, they do not appear to have achieved commercial importance.

Formaldehyde is sol in water and its 37% solution is the usual commercial product.
also sol in alc and eth

Both liquid and gaseous formaldehyde polymerize readily at low temperatures and can be kept in the pure monomeric state only for a limited time. Because of these facts, formaldehyde is sold and transferred either in solution or in polymerized form, such as paraformaldehyde and trioxane, described here under Formaldehyde Polymers Commercial, 37% solution of formaldehyde (So-called Methanol-free)

Clear, colorless liquid, d 1.1119 at 25°/25°; bp 101°; pH about 3.0; flash point 185°F; ignition temp about 80.6°F; methanol content about 0.4% by wt; RI 1.3777 at 18°

Uses of Formaldehyde. Consumption in the US increased from about 8.5 million pounds in 1914 to 500 million pounds in 1943

As a gas, it is used as a disinfectant. As a aqueous solution, it is used as a parent compound for preparation of numerous chemicals used in industry, such as in the manufacture of explosives, plastics, resins (eg phenol-formaldehyde resins etc) (See further under Formaldehyde and Derivatives, Explosives obtained therefrom)

When reacted with glycerin, it forms "glycerol formals" (qv)


Formaldehyde Polymers. Polymer formation is one of the most characteristic properties of the formaldehyde molecule. Two types of polymers exist: CH₂.O.CH₂.O.CH₂.O.

and .CH(OH).CH(OH).CH(OH).C., but only one, the first type, is called "formaldehyde polymer". Other name is "polyoxymethylene". Representatives of the 2nd type are encountered in the "polyhydroxyaldehydes". Carothers divides the polyoxymethylene into two groups: A- and C-polymers. A-polymers are formed by the polymerization of anhydrous monomeric formaldehyde:

H₂C:O + H₂C:O + H₂C:O + ... → .CH₂.O.CH₂.O.CH₂.O,

while the C-group is derived from aqueous formaldehyde involving formaldehyde hydrate (methylene glycol):

HO.CH₂.OH + HO.CH₂.OH + HO.CH₂.OH + ... → HO.CH₂.O.CH₂.O ... CH₂.OH + (n-1)H₂O.

These compounds are polyoxymethylene blycols. Walker (Ref 1, p 65 & Ref 3, p 142) gives a table describing the properties of various formaldehyde polymers

All of these polymers are linear with the exception of sym-trioxane [α-trioxymethylene] (HCHO)₃ and tetraoxymethylene (HCHO)₄, both of which are true polyoxymethylene, although they are not prep by the polymerization of monomeric formaldehyde

Of all these polymer's, Paraformaldehyde is the only one which is manuf on a large commercial scale. It is also known as Paraform, Polyformaldehyde or Polyoxymethylene. It can be represented by formulas (HCHO)ₙ or HO(CH₂O)ₙ in which n is equal to 6. It is wh solid w/ sl odor of formaldehyde; insol in alc, eth or w; sol in strong alkali solns. Can be prep by evaporating an aq soln of formaldehyde. Causes irritation of skin, eyes, nose and throat. Used as disinfectant, fungicide and in prep of some resins, artificial horns, ivory and explosives

The role of paraformaldehyde in prep of HM was discussed by Castorina of Pica- tinny Arsenal (Ref 2)

The polymer, sym-Trioxane, also known as α-Trioxymethylene, Metaformaldehyde, Triformol or Trioxin, can be represented as (HCHO)₃ or CH₂.OCH₂.OCH₂.O₂, consists of wh crys w/ formaldehyde odor, mp 62°, bp 115°, fl p (open cup) 113°F; sl sol in w; sol in alc & eth. Can be prep by distilla-
tion of formaldehyde. Used as a nonluminous, odorless fuel, as disinfectant and in org synthesis

The polymer, Tetraoxymethylene, (HCHO)₁, or Tetroxane, CH₂OCH₂OCH₂O₂ long, ndl like crystals, mp 112°; sol in acet, w, dil alkali & dil acid; vapor is stable at 200°; was obtd by heating a water-insol, polyoxyethylene diacetate of high mw.

It is readily converted to a polyoxyethylene when in the solid state (Ref 1, 3rd edn, p 194)


Formaldehyde and Derivatives (Explosives Obtained Therefrom)

A number of expls have been prepd from raw materials involving formaldehyde. Although most of the formaldehyde expls are prepd from formaldehyde derivatives, several expls can be prepd directly in one operation from formaldehyde or anhydrous formaldehyde, or its polymer, paraformaldehyde. Walker (Ref 38), in his book on formaldehyde, gives a brief description of expls derived from it. For convenience, we divide them into two groups — those obtained directly from formaldehyde and those from formaldehyde derivatives

1. Explosives Obtained Directly from Formaldehyde:

a) When concd nitric acid is mixed with formaldehyde, no visible reaction takes place, but if the mass is stirred, a violent, nearly expt reaction takes place (Ref 5)

b) When formaldehyde soln is nitrated at about 5°, the liquid expl, Methyleneglycol Dinitrate is obtained (Ref 25)

c) When anhydrous CH₂O, dissolved in ether, is treated with anhydrous H₂O₂, the liquid expl, Dimethyl Hydrogen Peroxide, is obtained (Ref 29). From the same reagents, a solid expl, Dimethylo Peroxide (qv) was also obtd (Revs 3 & 10). The methylol peroxide derivatives may be converted to peroxides of trioxane and tetraoxymethylene, such as liquid Pertrioxane and solid Tetroxymethylene Diperoxide, both of which are very expt (Ref 21)

d) Formaldehyde peroxides are also formed by the reaction of peroxide on paraformaldehyde

3) When formaldehyde (especially the commercial grade, ie containing paraformaldehyde) is treated with sodium peroxide, the reaction proceeds with expl violence (Ref 2)

f) When formaldehyde is treated with 3% H₂O₂ in the presence of (NH₄)₂SO₄, an expl product, Hexamethylenetetrahydroperoxide-diamine, (Ref 1) is formed. The same product was also obtd from hexamethylenetetramine and H₂O₂ (Revs 7 & 14)

g) When formaldehyde is treated at 40–50° with H₂O₂ in the presence of hydrazine sulfate, an expl peroxide compound called Trimethyleneperoxide Azine is obtd (Ref 7, p 490)

h) When formaldehyde (or paraformaldehyde) is treated with gaseous HCl and the resulting dichromethyl ether, Cl₂CH₁-O-CH₂-Cl, is nitrated, an expl oil, Nitromethoxyethyl Nitrate, is obtd (Ref 6)

i) When formaldehyde is treated with hydrogen peroxide in presence of ethylamine, a liquid expl, Dimethyleneperoxideethylamine, is obtd (Ref 7, p 497)

j) When formaldehyde reacts with hydrogen peroxide and urea, an expl, Tetramethylenediperoxidedicarbamide, is obtd (Ref 38, p 332 & Ref 4)

k) Dr Hans Walter prepd during WWII the explosive Formit (qv) by heating under reflux a mixture of 30% commercial formaldehyde with Amm Nitrate

2. Explosives Obtained from Derivatives of Formaldehyde:

An important group of expl organic nitrates is produced by the action of nitric acid on polyhydroxy compounds formed by the reaction of formaldehyde with ether al-
dehides, as well as with ketones and nitroparaffins

a) When formaldehyde is treated with acetalddehyde and the resulting compd (pentacythiotriyl, or PE) is nitrated, the final product is Pentacythiotriyltetranitrate, one of the most powerful expts, being only slightly less so than RDX (Ref 38, p 330).  
b) The following expts, derived from PE, were patented in Germany (Ref 28): Pentacythiotol Chlorhydrin Nitrates, PE Dicote Dinitrate, PE Diformate Dinitrate, PE Dimethyl Ether Dinitrate, PE Trinitrate, Mononitrobenzoate, PE Diglycolcolic Ester Tetratintrate, PE Monomethyl Ether Trinitrate.  In addition to these, Wyler (Ref 29) patented the expl PE Tetraacetate Tetratintrate.

c) Due to the fact that crude PE always contains variable amounts of by-product dipentaerythritol, after the nitrination of PE there is always present some Dipentaerythritol Hexanitrate (qv), which is a solid expl (Ref 30).

d) When formaldehyde is reacted with propionaldehyde and the resulting pentabuterol, CH₂C(CH₃OH)₃, is nitrated, a liquid expl, Trimethylolmethylenetrinitrate (Ref 15 & 22).

e) When formaldehyde reacts with isobutyraldehyde and the resulting pentaglycerol is nitrated, an expl Pentaglycol Dinitrate is obt (Ref 18).

f) When formaldehyde reacts with n-butyaldehyde and the resulting trimethylolmethane is nitrated, a solid expl Dinitrate is obt (Ref 17).

g) Formaldehyde reacts with ketones yielding products which give expls on nitration, such as Anhydroeneanethetiol Pentanitrate (Ref 37).

Friederich (Ref 23) prepd expl nitrates from products of reaction between cyclopentanone and cyclohexanone.

h) When formaldehyde reacts with nitroparaffins in presence of alkalis, the following general reactions take place:  
R.CH₂NO₂ + 2CH_Oaq = R.C(CH₂OH)₂.NO₂.  
These reactions were first studied by L. Henry in 1895.

Nitration of these compds yields products of the formula R.C(CH₂O.NO₂)₉.NO₂, some of which are useful as expls. For example, Nitroisobutylgleycin Trinitrate (Ref 1, p 331), Dimethylolmethylenitrato- methane Dinitrate (Refs 17, 35 & 39) and 2-Nitro-isobutanol Nitrate (Ref 35).

i) When formaldehyde reacts with ammonia, the following reaction takes place:  
6CH₂O + 4NH₃ + (CH₂)₆N₄ + 6H₂O.  The resulting product, Hexamethylenetetramine, is a parent substance for a number of expls, the most important of which is RDX or Cyclonite. Described in Vol 3 of Encycl, p C611ff as CYCLOTRIMETHYLENENITRAME.

j) Other expls derived from hexamethylenetetramine are: Hexamethylenetetraperoxide Diamine or HMTD (Ref 38, p 289 & 331 and Refs 12, 24 & 30); Hexamethylenetetramine Perchlorate (Ref 38, p 331 and Ref 34); Hexamethylenetetramine Trinitromethylcresylate (Ref 38, p 331 and Ref 9); Cyclotrimethylenetriminotriazine (Ref 38, p 332 and Ref 34).

Refs: 1) A. Bayer & V. Villiger, Ber 33, 2486 (1900)  2) L. Vanino, ZAnalChem 41, 619-20 (1902)  3) H. H. Fenton, JCS 106 (1), 1121 (1914)  4) G. von Girsewald & Siegins, Ber 47, 2466 (1914)  
Formaldehyde Gelatin or Glutofom. See under Formaldehyde-Starch Mixture.

Formaldehyde Peroxide. See Dimethylol Peroxide in Vol 5 of Encycl, p D1357.

Formaldehyde-Starch Mixture is, accdg to Hackh’s (1944), p 53-L, an antiseptic powder amyloform, used like iodole. He calls (p 381-R) the product of reaction of formaldehyde & starch glutil, while the name of glutol or glutofom is given in CondChemDict (1961), p 540-L to product obtd by the action of formaldehyde & gelatin. This product exists as a clear transparent mass which may be pulverized or a white to yel powder. It is insol in cold w but sol in hot w, under pressure.

Formalin. Same as Formaldehyde.

Formamide and Derivatives

Formamide or Methanamide, HCONH₂: mw 45.04, N 31.11%, mp 2.60⁰, bp 114⁰(18 torr), 10 3⁰(9 torr), sp gr 1.139 at 20⁰, nD 1.4481 at 20⁰, heat of combustion at const vol 136.7 kcal/mole; sol in w & alc; insol in benz & chlf; sl sol in eth. Prep by heating ammonium formate at 230⁰ in a closed tube (Ref 2), by heating ethylformate with NH₃ (Ref 3) or heating ammonium formate with urea at 140⁰ (Ref 4). Used as an industrial solvent.


Formamide Azide or Azidoformamide. See Carbamyl Azide in Vol 2, p C40-L, under Carbamic Acid and Derivatives.
Formamide Hydrochloride, CH₃NO + HCl; mw 81.51; ndls, insol in eth; stable when cold but explodes at 15° yielding NH₂Cl & CO (Refs 1 & 2). For this reason its use is limited: as there are few reactions that can be handled with so unstable a compd. Refs: 1) Beil 2, 5391 2) P.L. Magill, IEC 26, 613 (1934)

Formamide Perchlorate, H.CO.NH₂.HClO₄; mw 145.51. Acctg to VanDolah it combines low sensitivity to shock with high oxygen content. Refs: 1) Beil, not found 2) R.W. VanDolah, NavalOrdnMemorandumRept 10068 (1949) 3) CA, not found thru 1971

Formamidine. Acctg to Hack's (1944), p 352-L, formamidine is a compd contg the bivalent -N:CH.NH- radical, while guanyl (p 391-R) is the monovalent radical -C(NH).NH₂. Since the compds described below are listed in Beil and other refs under Formamidine, we are following their nomenclature and giving the name of Guanyl as an alternate.

FORMAMIDINES
Azidoformamidine or Guanylazide (Triazoformamidin, Carbamid-imid-azid or Kohlensäure-amid-azid, in Ger). N₃C(=NH)NH₂; mw 85.07, N 82.33%, OB -65.9%. Prep'd from the nitrate salt (which was prep'd from aminoguanidine nitrate and nitrous acid) by treatment with NaOEt in alc, but quickly rearranged to the Tetrazole. Consequently, it is known only as its salts. Ref: 1) Beil 3, 130, (60) & 12391

Azidoformamidine Hydrochloride, N₃C(=NH)NH₂.HCl; mw 121.54, N 57.63%, OB -46.1%; wh crysts, mp 126-146°(dec). Prep'd by refluxing in concd HCl - Guanyl-4(5-terrazolyl)-tetrazene Nitrate (Ref 2). Refs: 1) Beil, not found 2) S.H. Patinkin, J.P. Horwitz & E. Lieber, JACS 77, 562-7 (1955) & CA 50, 973h (1956)

Azidoformamidine Nitrate, N₃C(=NH)NH₂.HNO₃; (See also Vol 1, p A636-L), mw 148.08, N 56.75%, OB -10.8%; plates or prisms (from alc), mp 129°, expl at higher temp; sol in w & alc; in sol in eth, sensitive to friction, Trauzi Test value 400cc, deton vel 520 m/sec. Prep'd from action of nitrous acid on aminoguanidine nitrate (Ref 2) or treating a very cold soln of cyamamide in hydrazoic acid with cooled concd nitric acid (Ref 5). Refs: 1) Beil 3, 130, (60) & 12391 2) J. Thiele, Ann 270, 46 (1892) 3) K.A. Hofmann et al, Ber 43, 1095 (1910) 4) W.S. McEwan & M.W. Rigg, JACS 73, 4725-27 (1951) & CA 46, 4350 (1952) (Heat of comb) 5) W. Sauerlmilch, Explosivst 9, 256-57 (1961)

Azidoformamidine Perchlorate, N₃C(=NH)NH₂.HClO₄-1.5H₂O; mw 185.53 (-H₂O), N 37.75%(-H₂O), OB 0.0%; plates (from alc), sol in w. Prep'd from aminoguanidine nitrate, 20% HClO₄, and sodium nitrite (Ref 2). Detonates under impact, burns like smokeless propant. Refs: 1) Beil 3, 130 & 12391 2) K.A. Hofmann et al, Ber 43, 1095 (1910) 3) ADL, PureExpCompsds, Pt 4 (1952), p 567

Azidoformamidine Sulfate, CH₃N₃.N₂H₂SO₄; mw 183; colorless plts; readily sol in w; decmp in hot w and in dil sulfuric and nitric acids; deflagrates on heating. Refs: 1) Beil 3, 130 & 12391 2) R. Hofsommer & M. Pestemer, ZElCh 53, 386 (1949)

Azido-N-nitroformamidine, N₃C(=NH)NHNO₂; mw 130.07, N 64.61%, OB -12.3%; plates, mp 56°(dec, Ref 2), 79°(dec Refs 3 & 4); sol in eth, w, alc, chl & acet; insol in benz. Prep'd from Nitroaminoguanidine and nitrous acid at 0°(Refs 2 & 3). It is expl. Refs: 1) Beil, not found 2) T.E. O'Connor, G. Fleming & J. Reilly, JSocChemInd(Lond) 68, 30 9-10 (1949) & CA 44, 3443d (1950) 3) E. Lieber et al, JACS, 73, 1792-5, 2327-9
Azidoformamide Nitrate,
N₃C(=NH)₂.HN₃C₆H₅(OH)(NO₃)₃; m.w 314.18, N 35.66%, OB to CO₂ = -51.0 %
Refs: 1) Beil, not found 2) W. Sauermilch, Explosivst 9, 256-57 (1961)

Bromoformamide Nitrates,
BrC(=NH)₂.HNO₃; m.w 185.98, OB = -8.6%; colorless crystals, mp 65°, very unstable and expl, Trauzl Test value 170°C vs 400°C for the corresponding azido nitate (qv). Prepd by slowly adding cooled nitric acid to a very cold soln of cyanamide in 40% HBr (Ref 2)
Refs: 1) Beil, not found 2) W. Sauermilch, Explosivst 9, 256-57 (1961)

Bromoformamide Nitrate,
BrC(=NH)₂.HN₃C₆H₅; m.w 223.43, OB 0.0%; colorless hygroscopic crystals, mp 132°, expl at higher temp, Trauzl Test value 120°C vs 450°C for the azido nitate (qv). Prepd by slowly adding cooled concd HClO₄ to very cold cyanamide in 40% HBr (Ref 2)
Refs: 1) Beil, not found 2) W. Sauermilch, Explosivst 9, 256-57 (1961)

Chloroformamide Nitrate,
ClC(=NH)₂.HNO₃; m.w 141.52, OB -11.3%; colorless crystals, mp 120°, expl at higher temp; soly in w 7.9% at 0° and 22.2% at 30°. Prepd by treating cyanamide dihydrochloride in w withaq AN or from tech Ca cyanamide (Ref 2), also by adding cooled concd nitric acid to very cold cyanamide in HCl (Ref 3)
Refs: 1) Beil, not found 2) W. Sauermilch, Explosivst 9, 74 (1961) 3) Ibid, 256-57

Chloroformamide Perchlorate,
ClC(=NH)₂.HClO₄; m.w 179.00, OB 0.0%; cryst, mp 190°, expl at higher temp, soly in w 60.5% at 0° and 74% at 30°, Trauzl Test value 320°C and deton vel 4950 m/sec vs 40°C and 5200 m/sec for the azido nitate (qv). Prepd by adding cooled concd HClO₄ to very cold cyanamide in HCl
Refs: 1) Beil, not found 2) W. Sauermilch, Explosivst 9, 256-57 (1961)

1,1'-Azodiformamide Dinitrate,
[NC(=NH)₂.HNO₃]₂; m.w 240.14, N 46.66%, OB = -13.3%; yel crystals, plates (from w), with rapid heating expl at 180-184°C; sl sol in cold w; insol in alc & eth. Prepd by K permanganate oxidation of amino-guanidine nitate in nitric acid (Ref 2)
Refs: 1) Beil, not found 2) J. Thiele, Ann 270, 39 (1892)

1,1'-Azodiformamide Dipicrate,
[NC(=NH)₂.HOC₆H₄(NO₂)₃]₂; m.w 572.33, N 14.68% (NO₂), OB -55.9%; om-red plates, mp 179-180° (dec). Prepd from the dinitrate (qv) by displacement (Ref 2)
Refs: 1) Beil, not found 2) J. Thiele, Ann 270, 39 (1892)

1,1'-Azobis-nitroformamide,
[NC(=NC)₂.NH₂]₂; m.w 204.11, N 54.90% OB -15.7%; red or om-yel crystals (from CH₃NO₂), expl at 165°. Prepd from 1,1'-azodiformamide dinitrate by conversion to 1,1'-Azobis-chloroformamide, (=NC(=NC)₂.NH₂)₂, and then treating with nitric acid (Ref 2)
Refs: 1) Beil, not found 2) G.F. Wright, CanJ Chem 30, 62-70 (1952) & CA 47, 3793 (1953)

4-Formamino-1,2,4-triazole,
HCONHNCH=NN=CH; m.w 112.09, N 49.99%; crystals (from alc/eth), mp 117°, sol in cold w. Prepd by reacting dry formic acid and 4-aminio-1,2,4-triazole at 100°(Ref 2)
Refs: 1) Beil 26, 19 2) C. Bulow, Ber 42, 2717 (1909)

Formates. See under FORMIC ACID AND DERIVATIVES
Formation, Heats of. See Vol. 4, pp D369 & D370 and also in Tables A & B, pp D380 & D381

Formazans and Formazyls. According to Beil, 4, 4-5, formazan is the hypothetical parent compd HN=NCH=NH₂; and formazyl is the radical HN=NC(=)=NH₂; the latter may be considered the N-imino-N'-amino deriv of the guanyl or amidine radical HN₂C(=)=NH. This means that formazan may be called formazylhydride (Formazylwasserstoff, in Ger), although Hackel gives this name to the diphenyl deriv, PhN=NCH=NNHPh. Formazyl compds are said to have theoretically two isomeric forms: ArHN=CRN=Ar' and ArN=NCRNNHAr' by M. Ragni & S. Bruno who prepared various nitro derivs (Gazz. Chim. Ital. 76, 485-99 (1946) and CA 41, 6542 (1947)). For instance, the compd PhN=N(CN)=NNHPh may be called N,N'-Diphenyl-C-cyanoformazan or N,N'-Diphenyl-formazylcyanide. Some of the formazan or formazyl derivs give expl salts while others form tetrazoles or other ring compds. Note: C-Methylformazan is called Acetazidin or Azidin in Beil, 2, 4, but the name azidin has been suggested for the radical N₃C(=)=NH, which is entirely different.

Refs: 1) Beil 16, 25, [9] 2) E. Bamberger et al, Ber 27, 157 (1894), 33, 2059 (1900) & 34, 578 & 586 (1901)

N, N'-Diphenylformazan-C-Azobenzene (Formylazobenzol or Benzolazoformazyl, in Ger), PhN=N(C=NPh)=NNHPh; mw 328.38, N 25.60%; dark red leaflets, mp 162-3 °C; sol in hot alc; sol in acet., EtAc, chlfl & benz. Some of its salts are expl, eg: Copper(I) salt, CuC₁₉H₁₆N₁₆, greenish-black powder and Silver salt, AgC₁₉H₁₆N₁₆, dark violet powder with metallic luster. Both salts explode on heating. Refs: 1) Beil 16, 25-26 2) E. Bamberger et al, Ber 27, 149 (1894) & J PrCh [2] 64, 201 (1901)

N, N'-Diphenylformazylglyoxylic Acid (Formylglyoxylsäure in Ger), PhN=N(CO₃H)=NNHPh; mw 296.29, N 18.91%. Exists in two stereoisomeric forms: the red, mp 166 °C, gives expl Copper and Silver salts; the yellow gives a Silver salt. Refs: 1) Beil 16, 30 2) E. Bamberger et al, Ber 27, 152 (1894) & J PrCh [2] 64, 208 (1901)

Form Function. Consider that a chge of propnt consists of a number of geometrically similar propnt grains. Defining the size D of the propnt grain as the least thickness to be bunt thru for complete combustion of the grain, denoting f as the fraction of D remaining at time t, z as the fraction of wt bunt at time t, and S as the surface area of the grain at this instant, it is possible to relate z to f or S to z. It is British practice to use (z, f) relation, while US ballistics employ (S, z) relation. Either relation is known as the form function. See Ref for various equations employed Ref: SACMS, Internal Ballistics (1951), 40-52

FORMIC ACID AND DERIVATIVES
Formic or Methanoic Acid (Hydrogen Car-
boxylic Acid), H.COOH; mw 46.03; sp gr 1.2201 at 20/4°C, colorless liq with pungent odor; fr p 8.6°, bp 100.8°, RI 1.3719 at 20°, fl p 156°F; it is dangerously caustic; sol in w, alc, eth & glycerol. Can be prep'd by treating Na formate with sulfuric acid and distilling the formic acid in vacuo; another method is acid hydrolysis of methyl formate. It is formed as by-product in the manuf of PE from formaldehyde and acetalddehyde in presence of slaked lime (Refs 2 & 3)

Used for prepn of formates, org esters, oxalic acid, allyl alc, fungicides, insecticides, refrigerants, lacquers, electropolishing solns, and cellulose formate; also in silversing glass and as a rubber coagulant (Ref 5)


**Azidoformic Acid Ethylester** (Azidoaminoisäure-äthylester, Triazooamisensäure-äthylerster, Carbazidsäure-äthylester or Stickstoffkohlensäure-äthylester in Ger), N₃COOCH₃; mw 114.09, N 36.88%; liq, bp 114–15°C, 34°C (20.5 torr), sp gr 1.1082 at 20°C, nD 1.4162 at 25°C. Prep'd from N-aminoenethane and nitric acid (Ref 2), or by reacting NaN₃ with chloroformic acid ethylester (Ref 3)


**Azidoformic Acid Methylester** (Azidoaminoisäure-methylester, Triazooamisensäure-methylester, Carbazidsäure-methylester or Stickstoffkohlensäure-methylester in Ger), N₃COO.CH₃; mw 101.06, N 41.58%, OB −55.4%; colorless liq, bp 102–3°C; exploded occasionally when distilled under atm pressure. May be prep'd by warming for 1 hr ethereal soln of Am azide with methyl ester of chloroformic acid, Cl.CO.O.CH₃.


**Azidoformic Acid Dimethylamide**, N₃CON(CH₃)₂; mw 114.11, N 49.10%; liq bp 59°C (15 torr), expl when heated over a flame. Prep'd by boiling NaN₃ with chloroformic acid dimethylamide in acet (Ref 2)


**Ethyl Formate**. See in this Vol, p E294-R

**Glyceryl Formate**. See in this Vol

**Glyceryl Formate Dinitrate**. See in this Vol

**Glycol Formate**. See in this Vol

**Methyl Formate**, H.CO.O.CH₃; mw 60.05; colorless, flammable liq with agreeable odor; sp gr 0.974 at 20/4°C, fr p −99.8°, bp 31.8°C, fl p −32°C (−25.6°F), RI 1.3431 at 20°C; sol in w, alc & eth. Can be prep'd by heating methanol with Na formate and HCl, with subsequent distillation. Used in org synthesis, cellulose acetate solvent, fungicide and for prepn of military poison gases


**Sodium Formate**, H.CO.O.Na; mw 68.01; wh, sl hygroscopic powd; sp gr 1.919, mp 245°C (dec); sol in w; sl sol in alc; insol in eth. Can be prep'd by heating under pressure of NaOH with CO₂; purified by crystallization. Used as a reducing agent, mordant and manuf of formic acid, methyl formate and oxalic acid

US Military requirements and tests for Sodium Formate for use as a reagent are in Specification MIL-S-11168 (May 1951)


**Zinc Formate**. (HCOO)₂Zn.2H₂O; mw 191.45; wh crystals, sp gr 2.158 at 21°C; mp decomp at 175°C; sol in w; insol in alc or eth. Can be prep'd by the action of formic acid on Zn
hydroxide. Used as catalyst in manufacture of methanol; also as a waterproofing agent and wood preservative

Refs: 1) Gmelin-Kraut, not found
2) Sax (1968), 1245-R
3) CondChemDict (1961), 1245-R; (1971), 950-R

Formin or Glyceryl Formiate. See Formylglycerol in this Vol

Formit (Formite). One of the Ersatzsprengstoffe (Substitute Explosives) developed during WWII by an explosive group under the direction of Dr. Hans Walter. It was prepared by heating a mixture of 30% commercial formaldehyde with Amm Nitrate (in the ratio 6 moles HCHO to 6 moles NH₄NO₃) under reflux for about 1 hour, followed by vacuum distillation to remove the water and unreacted formaldehyde. The residue was a faintly yellow composition which consisted of MAN-Salz 25 to 30, TRI-Salz 1 to 3 and AN 67 to 74%. Its caloric value was 900 kcal/kg and volume of gases produced on explosion 1050 l/kg (calculated at 0° and 760 mm Hg).

When about 15% of RDX or PETN was incorporated, the velocity of detonation increased appreciably and the brisance was increased to that of TNT, while the volume of gases evolved on explosion was higher than for TNT. This explosive could be cast-loaded (setting point about 90°) in projectiles, but unfortunately it exuded at 60–70°. It was fairly stable to heat provided no iron impurities were present.

Note: MAN-Salz is Ger name for Methylamine Nitrate, while TRI-Salz is for Trimethylammonium Nitrate.

Refs: 1) H. Walter et al, "German Development in High Explosives", PB Rept 78271 (1947), p 4
2) A. LeRoux, MP 34, 132 (1952)
3) Fedoroff et al, PATR 2510 (1958), p Ger 52

Formoguanamine or 2,4-Diimino-tetrahydro-1,3,5-triazine, [HN=C(NH)NCH=N], isomeric with 2,4-Diamino-1,3,5-triazine, [H₂N₂C=NC(NH₂)=NCH=N], mw 111.10, N 63.38%, ndls (from w), mp 329°(dec); sol in boiling w; dif sol in alc; sol in dil HCl or warm dil sulfuric acid. Prepared by heating guanidine formate (Ref 2) or by treating biguanide hydrochloride with alcoholic KOH and chl (Ref 3). Forms a mononitrate salt (Ref 2)

Refs: 1) Beil 26, 225 & (65)
2) M. Nencki, Ber 7, 1584 (1874)
3) E. Bamberger & W. Dieckmann, Ber 25, 535 (1892)

Formula 226. See under Aluminum Containing Explosives, Vol 1, p A146-L

Formulation of an Explosive. In order to compose an explosive mixture suitable for certain kinds of work (mining, quarrying, ditching, stumping, etc), it is first necessary to know the proper proportions of the ingredients which one desires to use and the propensities required from such mixtures. For instance, in composing an explosive suitable for coal mining it is necessary to determine what gases will be produced on explosion and to calculate the total heat of combustion. This is done by adding the heats of combustion of ingredients and dividing by the average specific heat of the gases produced. This is called formulation. The formulation of explosives is a highly developed art which has resulted in the development of blasting expls which are quite safe to manuf, transport and use, and which develop their strength in the particular way best adapted to the needs of the special use for which they are formulated.

Formyl Explosive Compounds

N-(γ-Azidoformyloctyl)glycine Azide
(formerly called in Ger "Azidoglutarsäureglycinázid")₄N₄CO(CH₂)₄CONHCH₂CON₈; mw 239.21, N 40.99%, thick oil which expl when touched with a flame. Prepd by treatment of the corresponding dihydrazide with nitrous acid (Ref 2)

1-Formyl-2-picrylhydrazine,
HCONNH.C6H4(NO2)2; mw 271.15, N 25.83%, OB -56.1%; mp 188.5°(dec). Prepd by the reaction of Picric Acid with "isodiazomethane", (CH=N-NH)2, in eth, or by boiling picrylhydrazine with formic acid (Ref 2)

Refs: 1) Beil, not found 2) E. Müller & W. Kreuzmann, Ann 512, 264-275 (1934) & CA 29, 769 (1935)

Formylglycerol (or Formin) and Derivatives
Formylglycerol, Formin, Glycerin Monoformin or Glycerin Formate,
CH2(OCHO).CH(OH).CH2(OH), mw 120.10; liq, bp 154-57° at 10mm, d 1.3052 at 0°; nD 1.4614 at 12.5° (Ref 1). Can be prepd by treating anhydrous oxalic acid with glycerol acdg to the equation:

\[
\begin{align*}
\text{CH}_2\text{OH} & \quad \text{COOH} \quad \text{CH}_2\text{OCHO} \\
\text{CHOH} + \text{COOH} &= \text{CHOH} + \text{H}_2\text{O} + \text{CO}_2 \\
\text{CH}_2\text{OH} & \quad \text{CHOH} \quad \text{CH}_2\text{OH}
\end{align*}
\]

Served for prepn of expl dinitrate
Refs: 1) Beil 2, 24, (19), [34] & 1481 2) R. Delaby & P. Dubois, CR 187, 768, 950 (1928) 3) Naoún, NG (1928), 197

Formylglycerol Dinitrate, Dinistrosform or Glyceryl Formate Dinitrate,
CH2(OCHO).CH(OONO2).CH2(OONO2); mw 210.10, N 13.33%, OB to CO2 -22.2%; It yel oily subst. Can be prepd by the action of nitric acid on the product of the reaction of glycerol and oxalic acid, which is glycercyl monoformin, CH2(OCHO).CHOH.CH2OH. It is an expl compd, more brisant and powerful than Dinitosacetic, described in Vol 1 of Encycl, p A35-L, under ACETINS

Formylglycerol Dinitrate was proposed by Dr Vezio Vender and used in Italy as an ingredient of low-freezing Dynamites (freezing below -20°). It is, however, more expensive than other antifreeze compds and has no advantage over them. Its mixt with NG(30:70) has 90% of the power of NG

Dinistrosform decomp accdg to the equation:

\[
\text{CH}_2\text{(OCHO).CH(OONO}_2\text{).CH}_2\text{(OONO}_2\text{)} = 2\text{CO}_2 + 2\text{CO} + 2\text{H}_2\text{O} + \text{H}_2\text{O} + \text{N}_2\]

with evoln of 1009cal/g at Cv and H2O liq. Its heat of expln is 68% that of NG

Refs: 1) Beil 2, 24 2) Naoún, NG (1928), 197 & 374 3) Davis (1943), 222

N-(β-Azidoformylpropionyl)glycine Azide
(formerly called in Ger "Azidosuccinyl-glycinazid"),
N2CO(CH2)3CONHC2H2CON, leaflets, mw 225.17, N 43.54%; expl when touched with a flame. Prepd by treating the corresponding dihydroaze with nitrous acid (Ref 2)


Formylhydroperoxide or Performic Acid
(formerly Perameisinsäure in Ger),
HCO.O.OH; mw 62.03, OB 0.0%. Prepd as a 90% soln by distilling a mixture of formic acid, 100% hydrogen peroxyde and sulfuric acid (Ref 2). The soln is more volatile than formic acid, is miscible with water, alc, eth and readily sol in benz or chlor.

Metals and metal oxides may cause it to dec explosively. The soln is not stable even at 0° and can explode when shocked or heated

Formvar. A polyvinylformal insulating agent manufd by Bond Master Rubber Adhesive Co, Irvington, NJ, used in conjunction with bonding agent "Areldit" (epoxy resin of Ciba-Geigy Corp, Ardsley, NY) in some US military detonators, such as T44
Refs: 1) P.B. Tweed, Ordn 44, 654 (1960)
2) P.B. Tweed, formerly of PicArsn; private communication (1960)

Forster (von) patented at the end of the 19th century a smokeless propint prepd by treating with 2:1 ether-alcohol a mixture of 80% Guncotton with 20% Collodion Cotton. The resulting partially gelatinized product was rolled into sheets of 0.1mm thickness and cut into grains 2x2mm. As the surface of grains was rough, they could be dried quicker than grains with smooth surface obtbl with completely gelatinized propiants
Ref: Daniel, Dict (1902), 304 & 793

Fortex. Two expls patented in France in 1910 were:
Fortex No 1: NH₄NO₃ 70 & Tetryl 30 and
Fortex Antigrisouteux: NH₄NO₃ 78.5 & Tetryl 21.5%. Calculation showed that OB to CO₂ of the first expl was practically zero, while for the second there was an excess of oxygen. They were not authorized by the Commission des Substances Explosives (French Explosives Commission) (Ref 1). A new Fortex is one of the few commercial expls based on Tetryl: Tetryl 12, Amm Nitrate 35, K nitrate 35 & Amm chloride 20 (Ref 3)
Refs: 1) H. Dautriche, MP 17, 177–79 (1914) & CA 8, 1208 (1914) 2) Colver (1918), 373 3) Thorpe 4, 487 (1940) 4) Clift & Fedoroff 2 (1943), p F3

Fortification or Reviviscence of Acids. In the manuf of expls, such as NC, NG, TNT, PETN etc by nitrination, the main reaction results in the consumption of a certain quantity of nitric acid and the formation of an equivalent quantity of water. The resulting spent acid is usually too weak for nitrations, but in some cases it may be fortified (in works' parlance, "butted-up") by the addition of concd nitric acid (60–99%) and oleum or by a suitable strength mixed acid

Sometimes, for example, in the nitration of toluene to Mononitrotoluene, the spent acid contains so much water and so little nitric that it is impossible to fortify economically with nitric acid and oleum. In this case the acid (commonly called "waste acid") has to be distilled in order to recover the nitric acid, and the remaining sulfuric acid is concd to about 95% strength. Examples of Calculation. Assuming that a spent acid ("di-spent") left after the dinitration of toluene with a composition which is as follows: total H₂SO₄ 74.6, total HNO₃ 12.6 (actual HNO₃ plus oxides of N calcd as HNO₃), H₂O 14.7, and that it is desired to fortify it to obtain a mixture with the composition: total H₂SO₄ 66.3, total HNO₃ 21.4 and H₂O 7.8%. The calculation would proceed as follows: to the waste acid add a volume of a mixture containing (Qx'–x%) each of H₂SO₄, HNO₃, and H₂O, wherein x' is the desired %, x is the % in the waste acid and Q is the ratio of the new total volume to the volume of waste acid
The above described method of calcn was used during WWII at the Keystone Ordnance Works, Meadville, Pa

Explanation of terms total H₂SO₄, total HNO₃, actual HNO₃, etc is given in Vol 1 of Encycl, under "Acidity in Acids", pp A88-R to A90-R

Fortis. Accdg to Daniel (Ref 1, p 304) it was a powder which is also known as Polynitrocellulose, Poudre d'Heusschen, Glyceronitre or Benzoglyceronitre. The
Fortis No 1, patented in England in 1884, had the following compn: K nitrate 57.00 to 93.19, sulfur 8.00 to 12.00, tanbark 15.00 to 25.00, lamplblack 2.00 to 3.00, Fe sulfate 1.35 to 27.80 & glycerol 0.95 to 1.84%. The Fortis 2 contd besides the above, naphthalene and Na nitrate. It was claimed that when these mixtures were initiated, some NG was produced right in the boreholes.

The following Fortis was patented in France in 1891 (Ref 1, p 305): K or Na nitrate 65, sulfur 13, carbon 12 & DNNaphthalene 10%. The same expl is listed by Gody (Ref 2), but %age for DNN is given as 12%, which is evidently wrong because the total makes 107% instead of 100%. This Fortis was manufd by the SA des Poudrieries Belges at Hérénhals and was admitted to England (Ref 1). Daniel (1902), 304-05 2) Gody (1907), 173

Fortisine. A mixture of K nitrate 74.8, charcoal 14.4, sulfur 6.3, DNB 4.1 & moisture 0.4%
Ref/s: 1) Daniel (1902), 305 2) Fedoroff & Clift 4(1946), 36

Forty-Degree Test for Exudation (Sweating) of Explosives. This test is known in France as "Exsudation par évaporation". It is described in Vol 1 of Encycl, p XI.

A similar British test, known as "Keeping Test" is described in Ref 1.

The American Forty-Degree Test is one of the tests conducted at the Bureau of Mines, Pittsburgh, Pa for determining whether a Dynamite exudes or not. Although the official US Bur of Mines test is the Centrifuge Test (described in Vol 2 of Encycl, p C31-R), other tests may be used especially if there is no centrifuge available.

Following is the procedure for Forty Degree Test:
1) With the aid of a thin aluminum wire, make several small perforations thru the wrapper on one end of the Dynamite cartridge
2) Place the cartridge upright on the perforated end in a small wire tripod located inside a tall glass beaker or a glass cylinder
3) Place the ensemble into a constant temp oven maintained at 40°
4) At the end of six days, remove the cartridge and examine to determine if any drops of NG or other liquid have formed at the perforated end.

If drops are found, the expl is considered to contain too great a percentage of NG, or other liquid ingredients, for the amount of absorbents present and the composition should be changed accordingly.

Forty-foot Drop Test. A complete description of the procedure is given as test No 103 of MIL-STD-331. See Vol 4, p D1093-R, Test 13

Forty Percent Dynamite. See Farmer's Dynamite

Forty-two Grain Powder. A sporting shotgun powder of such apparent density that 42 grains are required as a charge for a 12-bore cartridge, in order to occupy the same space as 82 grains of Black Powder. Schultze, Amberite, Ruby, Felixite, Primrose Smokeless, Coopal No 1, KS Powder etc belonged to this class of powder. Some of the 42-grain powders are probably still used occasionally, but the powders for which smaller charges are required (such as 33-grain powder) are preferred because they give lighter recoil and burn quicker. Reduction of charge is effected by using a NC of higher nitrogen content and reducing the proportion of other ingredients. These changes increase the rate of burning which might result in the development of dangerous pressures in the gun. In order to slow down these
powders, more complete gelatinization of the NC is required
Ref: Marshall 1, (1917), 326

Fossano (Polvere). One of the older Italian Black Powders
Ref: Daniel (1902), 305

Fossano Powder. A progressive burning powder which was prep’d as follows: Black Powder, as it comes from the mill (‘mill cake’) was pressed to a density of 1.79 and then broken into 1/8” to 1/4” grains. These grains were mixed with fine Black Powder and the resulting mixture pressed into grains 2 1/4” x 2 1/4” x 1 3/8” with an average density of 1.76. This powder may be considered as a development of “Doremus Cartridge”, described in Vol 5 of Encycl, p. D1335-L.
Ref: Van Gelder & Schlattek (1927), 26

Fossil Flour. Same as kieselguhr

Fougasse or Fugas (Rus). A kind of landmine prepared by burying several feet underground a large charge of explosive (such as BkPdr), placing on top of it heavy stones or metallic objects, and covering the ensemble with earth. The chge of expl was detonated by fuse or by electric cap when a vehicle or body of troops approached or went over the fougas.

Fougasses can also be placed in tunnels dug underground towards enemy’s fortifications and then exploded under them. This is done in order to make an opening (breach) in the wall (called in Russ “bresh”) or to destroy the fortification gate
Ref: F. Pavlenkoff, “Entsiklopedicheskii Slovar” (Encyclopedic Dictionary), St. Petersburg, Russia (1913), p. 2770 (Reproduced by Bookstore N.N. Mart’ianov, 243 W56 St, New York 10019

Fougasse (Fr). A kind of land mine prepared by digging underground an inclined hole in the form of truncated pyramid and burying in it an hermetic box containing explosive. This was covered with a template, heavy stones, and earth. Detonation of expl chge was done either by fuse or by electric cap
Ref: Daniel, Dict (1902), 307–08

Fougasse, Incendiary Fuels for. Exptl work on fillings for fougasses led to the following compn: 60 gals gasoline, 55 gals rubber latex, 40 gals alc., 25 lbs stearic acid and 7 pts NaOH soln of sp gr 1.43
Ref: J InstPetroleum 34, 90–108 (1948) & CA 42, 3961 (1948)

Fougasse (US). Accdg to definition given in Glossary of Ordn (1959), p 122-L, it is a mine constructed so that upon expln of the charge, pieces of metal, rock, gasoline or other substances are blown in a predetermined direction

Fouling of Guns and Antifouling Agents.

The advent of smokeless propells required the coating of the lead bullet, normally with a Cu-Ni alloy. With repeated firings some of this alloy builds up inside the gun barrel, trapping acidic residues from the propellant and primer. The result is severe corrosion of the barrel and interference with the ballistics of the bullets from increased friction. Preventive measures involved the incorporation of various metal scavengers into the propellant as exemplified in Refs: 1) 1–5% Pb or Sn oxide or carbonate; 3 & 4) aromatic or aliphatic Sn compounds; 5 & 6) 0.25–2.0% Sb oxide or sulfide, Cd metal, oxide or carbonate, Co, MnO₂, ground glass or calcium silicate; 7) CaH₂. Barrel cleaning formulations based on an alkaline oxidizing agent were typified by Refs: 2) aqueous (NH₄)₂SO₄, (NH₄)₂S₂O₃, NaOH – dissolved just before use; and 8) aqueous NH₄OH, oleic acid, K₂Cr₂O₇ and H₂SO₄, in de-
creasing order

One of the devices used occasionally by the Russians for preventing excessive fouling of gun barrels was a lubricator, called *prosas*l'nik (*"lubricating gasket"* in Engl and *"Dichtungsdeckel"* in Ger). Accdg to a brief description given in Ref 9, the device consisted of cardboard obturator, cardboard covers (between which was placed a thick ring consisting of a lubricating mixture of red lead, cerasin and vaselin) and a gasket. It was usually mounted on the boat tail (or base) of the projectile during loading. It was claimed that proplnt gases caused the "prosas*l'nik" to disintegrate and the lubricating material to be spattered inside the bore, thus depositing a protective insulating coating on the bore surface.

It was claimed by the Russians that "prosas*l'nik" increased the life of the guns, but accdg to some American sources, the use of bore lubrication decreased the muzzle velocity.

Accdg to J.E. Capell, formerly of Pic-Arsenal, some other (than US or Russia) countries tried friction lubricants, but they did not think that they were of great value (See also Decoppering Agents in Vol 3, p D36-R).

*Refs: 1) C. Henning, USP 1357865 (1920) & CA 15, 315 (1921) 2) R. Laughlin, USP 1535124 (1925) & CA 19, 149 (1925)
3a) Imperial Chemical Ind Ltd, FrP 708855 (1931) & CA 26, 1125 (1932) 3b) Ibid, FrP 730728 (1932) & CA 27, 419 (1933)
3c) Ibid, BrP 373152 (1931) 4) R. Burns & O.W. Stickland, USP 1943421 (1934) & CA 28, 2188 (1934)
5a) H.N. Marsh, USP 2131061 (1938) & CA 32, 9504 (1938)
6) Hercules Powder Co, BrP 508914 (1939) & CA 34, 3092 (1940) 7) V.N. Poddubny, TekhiVoruzhhenie 1938, 60-7 & ChemZentr 1938, II, 1480 & CA 34, 5037 (1940)
8) C. Hardy, USP 2301043 (1942) & CA 37, 2185 (1943) 9) Fedoroff et al, PATR 2145 (1955), p Rus 19-L*  

**Four Cartridge Test.** German test designed to determine the ability of mining explosives to transmit detonation. It is called *Detonationfähigkeit Probe* and was conducted as follows:

Four cartridges, 35mm in diam., were laid end to end on a bed of sand and then one side of the train was detonated by a No 3 Blasting Cap. It was required that all four cartridges be detonated completely.

It is one of the "Detonation by Influence Tests", listed in Vol 1, p X and in Vol 4, pp D395-R to D402-L. The most important of these tests are "Gap Tests". They are briefly described in Vol 1, pp XIV & XV and listed in Vol 4, pp D303-R & D304-L. The LSGT (Large-Scale Gap Test), designed by Donna Price, is described in Vol 4, pp D318-R & D319-L. The NOLR (Naval Ordnance Laboratory) Gap Test is on pp D321 & D322-L and its modification on p D327, Fig 8. The SSGT (Small Scale Gap Test) is briefly described on pp D318 and more fully by J.N. Ayres in NavWepsRept 7342 (1961) and by Donna Price in NOLTR (1966), which is abstracted on pp D343-R to D345-L with Fig 35 on p D344.

**Refs for German Test:** 1) BIOS Final Rept 1266 (1942), p 2 2) Fedoroff et al, PATR 2510 (1958), p Ger 52-R

**Fourcroy-Vaquelin Detonating Mixture,** proposed in France about 1790, consisted of powdered potassium chlorate mixed with powdered sulfur. Calcium or sodium chlorate in lieu of K chlorate were also tried. All of these mixts were extremely dangerous to handle.

*Refs: 1) M. Specer, SS 26, 372-73 (1931) 2) Ibid, SS 27, 332 (1932)*

**Fournier Powder** (Brit). Patented in 1870; was prepd by heating a mixture of 125 parts Ca carbonate and 65 psi NaCl, all well covered with urine. After evaporating nearly to dryness, 35 psi of carbon was added and the mass well mixed.
Refs:  1) Daniel (1902), 308  2) Fedoroff
& Clift 4(1946), 36

**Fowler Dynamite.** One of the Ital "dina-
mite a base attiva": NG 20.00, AN 56.25,
carbon 5.00 & Ca sulfate 18.75%
Refs:  1) Daniel (1902), 305  2) Giua,
Trattato VI(1)(1959), 340

**Foxhole.** Small pit used for cover of one or
two soldiers. It is so constructed that an
occupant can fire effectively from it
Ref:  Glossary of Ordn(1959), 122-L

**Foxhole Explosive Digger.** The Harve Ma-
achine Co design consists of a finless rocket
with a 1-3/8-inch motor containing 0.18 lbs
of a double-base propmt and a head contg
0.56 lbs of HBX. The rocket head is de-
ominated by a vane type fuze, the vanes of which
are turned by the earth as the rocket
penetrates. Suspended from the front of the rocket
is a small shaped chge that is fired by the
fuze ogive upon the initial movement of the
rocket

The whole assembly is suspended near
its center of gravity from a simple lightweight
tripod launcher. The assembly is folded and
inserted into a water proof tubular fiberboard
container and the legs of the launcher are
used to hold the rocket and shaped chge sec-
curely in the packed condition. Also one leg
carries a safety pin for the fuze while a se-
cond carries a leg extension

The rocket is fired by an M2 Fuse and
about 16 inches of safety fuse

It should be noted that the Rocket-Shaped
Charged-Launcher combination comes as a
complete assembly and needs no field assembly
or disassembly. This item is intended for one
use only — a one shot cratering device. It
must be emphasized that the Explosive Fox-
hole Digger, if properly used, can be a valu-
able tool, but if not properly used, can be a
hazardous expl item. All possible safety
has been designed into the item, but nothing
can render it safe from intentional misuse
Ref:  Staff, Harve Machine Co Inc, Torrance,
California, "Characteristics and Operation of
Harve Machine Co, Inc Design Explosive
Foxhole Digger" (June 1957) (Contract
DA-44-009-Eng-2906 for Corps of Engineers,
Fort Belvoir, Va)

**FP.** Amer abbr for "Flashless Propellant"

**Fp.** Ger abbr for Füllpulver which is any high
explosive used for filling shells, bombs,
mines, torpedoes or grenades. It may be
called filler or bursting charge

Fp 02 (Füllpulver 02). Explosive Pattern
1902 or TNT

Fp 88 (Füllpulver 88). Explosive Pattern
1888 or PA

Fp 60/40 (Füllpulver 60/40). Amatol contg
TNT 60 & Amm Nitrate 40%
Ref: PATR 2510(1958), p Ger 52-R

fps. Amer abbr for "feet per second"

**Fractionation Columns (Towers or Tubes) are
devices used in fractional distillation (See
also under DISTILLATION in Vol 5, p
d1510-L)

The most commonly used types of columns
are: plate columns, Vigueux columns, packed
columns (packed with such materials as Raschig
rings, Berl saddles, fibrous glass etc)
Refs:  1) C.S. Robinson & E.R. Gilliland, "The
Elements of Fractional Distillation", McGraw-
Hill, NY (1939)  2) A. Rose, IEC 33, 594
(1941)(Batch fractionation)  3) D.F. Othmer,
ChemMetEng 49, 84(1942)(Distillation prac-
tices and methods of calculation)  4) G.W.
Minard et al, TransAmInstChemEngrs 39, 813

Fractorites. European Dynamites, listed in Table F13 are taken from the book of Gody (Ref 1, pp 712, 713 & 715). The 1st and 3rd comps are also listed in Thorpe (Ref 2) and in Ref 4. The 3rd comp is also listed by Naoum (Ref 3)

Table F13
Fractorites

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<th>AN</th>
<th>Colophony</th>
<th>Dextrine</th>
<th>K dichromate</th>
<th>Amm oxalate</th>
<th>Amm chloride</th>
<th>DNN(Dinitronaphthaline)</th>
<th>Na nitrate</th>
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Other ingredients were not given in Ref 6


Fracturing in Oil Shale by Explosives. BuMines developed methods for fragmenting oil shale formations with chemical explosives to prepare oil shale for in situ retorting and to evaluate the extent of fragmentation by various methods. A combination of three methods of explosive fracturing was used: (1) The displacement and detonation of a liquid chemical explosive in a natural fracture system; (2) the use of 60-pct dynamite to relieve stress conditions of the rock around the wellbore; and (3) the use of pelletized TNT in a series of wellbore shots to fragment the oil shale. The data from the seismic measurements indicated the extensively fragmented zone was approx 95 ft in diameter and 70 ft thick Refs: 1) J.S. Miller & H.R. Nicholls, "Methods and Evaluation of Explosive Fracturing in Oil Shale", USBurMines Report of Investigation RI 7729 (1973), Pittsburgh, Pa, 19213 2) G. Cohn, Ed, Explo&Pyrots 7(2), 1974

Fracturing of Corner in Detonation. See Vol 4, p D543-R

Fracturing of Metal in Detonation or Fracturing of Metal Under Impact Loading by High Explosives. See Vol 4, p D542-R

Fracturing of Rock by Shock-Wave in Detonation. See Vol 4, p D545-R and Table 2 on p D546

Frag. Abbr for Fragment or Fragmentation

Fragmacord Mine. A new concept of linear A/P (antipersonnel) mine which combines heavy detonating cord with a fragmenting
system, consists of a 25-foot length of flexible expl cord 1/2 inch in diam, tightly bound at 1/4 inch intervals with metal rings notched to break into at least 12 fragments each when the cord is detonated. Thus, from a 25-foot length, at least 3000 fragments are produced. The new mine is versatile, being easily portable and quickly emplaced, and hence was well suited for such unconventional combat situations as were commonplace in Vietnam


**Fragment.** A piece of an exploding or exploded bomb, projectile or the like

*Ref: Glossary of Ordn (1959), 122-L*

**Fragmentation.** Term applied to ammunition, indicates that the item is primarily intended to produce a fragmentation effect

*Ref: Glossary of Ordn (1959), 122-L*

**Fragmentation Bombs** are described in Vol 4, pp D933 to D935. One of such bombs, 90-lb Frag Bomb, M82 is shown in Fig 2-2 on p D935

**Fragmentation Characteristics.** As a manifestation of expl output fragmentation is characterized by velocity and size distribution of fragments. For some purposes, the size and shape of fragments are predetermined either by preforming or by modifications of the case or chge design which predisposes it to break as desired

The initial velocity of fragments is quite accurately predicted by the Gumey formulas described by us under "Gumey Constant and Gumey Formulas" in Vol 6 of Encycl.


**Fragment Concentration Test.** See Density of Fragments (Splinters) Test in Vol 3, p D84-L and in PATR 2510, p Ger 52-R

**Fragmentation, Controlled.** Since the breakup of chge cases under expl attack is mainly two dimensional, the average size of fragments may be reduced and their number increased by the use of multiple walled cases. Many other methods were developed to produce fragments that are almost all of the optimum size and shape. These methods include:

a) Preformed fragments with or w/o matrix
b) Notched or grooved rings
c) Notched or grooved wire
d) Notched or grooved casings
e) Fluted liners
f) Preformed rod fragments. They are more effective against aircraft than the same weight of metal broken into smaller pieces.

There are two systems:

*Discrete rod warhead consists of a number of rods (usually of steel) arranged like the staves of a barrel to form a cylindrical container which is provided with covers. The rods are joined together to provide a needed structural strength for handling, launching and flight but not to prevent their separation under the action of the expl, which is placed inside the container. Continuous rod warhead consists of rods that are strongly joined to one another at alternate ends in a manner similar to that of a folded carpenters' rule. The hoop breaks when its circumference equals the sum of the rod length, if excess energy is imparted by expl.

*Ref: AMCP 706-179 (1974), p 3-16*

**Fragment Density Test.** Same as Fragment Concentration Test

**Fragmentation Grenades,** such as: Fragmentation Hand Grenades. See Vol 4, pp D830 & D831 and Figs 1-20a, 1-20b & 1-20c
When grenades are fired from rifles, they are called *Rifle Grenades*. They can be either especially designed or adapted to be fired or launched from the muzzle of a rifle or carbine. 

Ref: Glossary of Ordn (1959), 138-39

**Fragment Gun.** See Vol 1, p XII

**Fragment Gun Test (FGT).** See under Fragment Gun. The FGT values for several expls are given under BRISANCE in Table 1 of Vol 2, pp B266 to B295.

**Fragmentation Tests in Detonation and Explosion.** These tests were designed to determine the actual performance (efficiency) of an expl projectile or any of its parts. They permit the approx estimation of thebrisance of the expl used in the projectile. Refs for these tests are given in Vol 1, p XII and a list of various fragmentation tests is given in Vol 4, p 303-L, under Experimental Procedures. The so-called Closed Pit and Open Pit Tests are described in Vol 3, pp C345-R to C350-L. For other information, see individual comps; eg Comp B Table, Vol 3, p C479, etc.


**Fragment Velocity Measurements.** In addn to a brief description given in Vol 1 of Encycl, p XIII, the following may be included:

The faster the fragments of a bomb or a shell fly, the more damage they might cause to a target. It is important for this reason to be able to determine their velocities and this info will be useful in deter the relative brisance of the expl with which the projectile is filled.

The US Ordnance method employed during and after WWII for detg fragment velocity utilized high-speed motion cameras, which could be operated at speeds as high as 14000 frames per second. The test has been conducted (behind a barricade) by suspending the round of ammunition at a certain measured distance from metal (such as “dural”) targets to be photographed, located near the fragment recovery boxes. A mirror was placed to reflect an image of the round to the camera.

When prepns were completed, the cameras were started and the round fired. If the velocities of fragments were higher than 1700–1800fps, light flashed results from fragments impacting upon the metal target and these flashes were recorded by camera. By knowing the distance from round to target and time elapsed, it was possible to determine the velocity. After the firing was over, the testing personnel returned to the scene in order to collect the fragments, record the location of each fragment on the target and to weigh each fragment.

For more info see Refs of which Refs 1 & 6 describe methods for detg fragment velocities using argon light chronograph (See also “Guemey Constant” and “Guemey Formulas” in this Vol and in Refs.

Refs: 1) ARD (Armament Research Dept) Explosives Report 31/43–AC 3430–SD/FP74
Franchimont Reaction. By the action of KCN on α-bromo acids or esters, α-cyano-α,β-dicarboxylic acid derivatives are formed which on hydrolysis and decarboxylation yield α,β-dicarboxylic acids:

\[ 2C_8H_5CHBr.COOR + KCN \rightarrow \]

\[ C_8H_5-C(CN)-COOR + H_2O \quad C_8H_5-CH.COOH \]

\[ C_8H_5-C(CN)COOR + 2C_8H_5.CH.COONa \]

Ref: The Van Nostrand Chem Dict (1951), 303-R & 304

François Blondel (1617–1686). A Fr ballisticien who published in 1685 a treatise entitled "L'Art de Jeter les Bombes"

Ref: A. Basset, MAF 10, 612–21 (1931)

Frangible Ammunition (Frangible Bullets and Frangible Projectiles). Frangible bullets are described under BULLETS in Vol 2 of Encycl, pp B331-R & B332-L and in Refs 1 & 3

Under the title Frangible Projectiles, Welden patented (Ref 2) projectiles congt 75–90% finely divided metal filings and 25–10% thermoplastic resinous binder. Such projectiles (bullets) were suitable for use in .22 cal cartridges generally used in shooting galleries and for other types of gunnery training. They eliminated many of the hazards accompanying the use of the lead projectiles which are commonly employed


Frangible Hand Grenade. Improvised incendiary hand grenade consisting of a glass container filled with a flammable liquid and provided with an igniter. It breaks and ignites upon striking a resistant target, such as a tank. The so-called "Molotov Cocktail" consisted of a glass bottle filled with a flammable liquid such as gasoline or benzene. After closing the bottle, a piece of fabric was wrapped around its neck. Before throwing the grenade, the fabric was soaked with a concd soln of white phosphorus in carbon disulfide.
As soon as part of carbon disulfide evaporated, P on coming in contact with air ignited and its flame ignited the flammable liquid of grenade.

Another type of frangible grenade was filled with a mixture of K chlorate 80 & Nitrobenzene 20%, called "Russische Cocktail" (Russian Cocktail) by Stretsbacher. This mix ignited on being touched with a drop of concd sulfuric acid. The reaction proceeded as follows:

$$25 \text{KClO}_3 + 6 \text{C}_6\text{H}_5\text{NO}_2 = 36\text{CO}_2 + 15\text{H}_2\text{O} + 25\text{KCl} + 6\text{N}_2$$

generating heat equal to 1182 kcal/kg

Refs: 1) A. Stretsbacher, Protar (Swiss) 10, 160 (1944)  2) Fedoroff et al, PATR 2145 (1953), p Rus 20-R  3) Glossary of Ordn (1959), 138-R (Grenade, Frangible)

**Frank, Adolph** (1834–1916), German industrial chemist who developed the potash industry

Ref: Hack's (1944), 355-L

**Frangible Projectiles.** See under Frangible Ammunition

**Frank** patented in France in 1886, mixtures of nitrate benzene, phenol, naphthalene or naphthol with solid oxidizers, using as binders non-explosive substances, such as drying oils, soln of colloidion or of gum, etc

Ref: Daniel, Dict (1902), 309

**Frankel** patented in France in 1888 & in 1899 powders consisting of K(Na, NH₄ or Pb) nitrate impregnated with a molten hydrocarbon (such as a mixt of naphthalene with paraffin). Such mixtures were activated by addn of powdered K chlorate just before use

Refs: 1) Cundill (1899) in MP 5, 338 (1892)  2) Daniel (1902), 308

**Frank Explosives.** Ammonium nitrate explosives, patented in 1895 in Germany, contd as an additive K permanganate and/or chromate or bichromate. This was done in order to increase the power and sensitivity to initiation and to decrease the hygroscopicity.

For example, if to an expl with low temp of expln and low sensitivity to initiation, such as the one contg 96% AN and 4% MN-Naphthalene, was added 4% K permanganate, the power, as derd by Trauzi Test, was nearly doubled and its sensitivity was increased to the point that it was possible to use for initiation No 3 cap (0.53g MF) instead of No 6 cap (1.0g MF)

Refs: 1) Daniel (1902), 308–09

**Frankford Arsenal.** One of the US Arsenals listed in Vol 1, p A490-L. It is a field installation of the Army Materiel Cmd located in Philadelphia, Pennsylvania charged with the responsibility for development, procurement and associated activities for off-carriage fire control systems, and on-carriage fire control components; also has responsibilities with respect to small arms ammunition, artillery cartridge cases, projectiles & mechanical time fuzes, standard inspection gages & measuring equipment, and metallurgical research & engineering. Also responsible for development of recoilless rifles & ammunition


**Frank-Kamenetskii Thermal Explosion Theory.**

A thermal explosion theory as developed by D.A. Frank-Kamenetskii (Ref 5) led to the equation

$$\Delta T = -\frac{Q}{\lambda} \exp\left(\frac{E}{RT}\right) \exp\left(\frac{E}{RT}\right) \exp\left(\frac{1}{T-T_0}\right)$$

The ignition temp expln limits so calcd agree with those experimentally found for azomethane by Rice (Ref 1), MeNO₂ by Appin, N₂O by Zel’dovich and Yakovlev (Ref 4), and for H₂S by Yakovlev and Shantarovich (Ref 3). The expl limit calcd for N₂O was subsequently found experimentally. With Et azide, the calcd
values disagree with the exptl values of Rice and Campbell (Ref 2). Also see Vol 4, pp D408-R & D409-L


Ref: Hackh’s Dicz (1944), 355-L & 498-L

Frankland Reaction is the synthesis of hydrocarbons by zinc-alkyl condensation:

Zn(CH₃)₂ + 2R.Br = 2R.CH₃ + ZnBr₂

Ref: Hackh’s Dicz (1944), 355-R

Franklin, Benjamin (1706-1790). An Amer statesman, printer, scientist and writer, born in Boston; went to Philadelphia in 1723. Architect of the Declaration of Independence and Constitution. Minister to France. First postmaster. Known internationally for his common-sense philosophy. For details, see his writings or any Encycl. Inventor of elect initiation (Ref 1)

He founded the American Philosophical Society and developed some fertilizers (Ref 2)

Refs: 1) C.E. Munroe, “Benjamin Franklin’s Unheralded Achievement”, Explosives Engineer 3, 115-18(1925) 2) Hackh’s Dicz (1944), 355-R

Franklin, Edward C. (1862-1937). An Amer chemist noted for his theory of the ammonia system compounds (Ref, p 355-R)

It is a system of acids, bases and salts with liquid ammonia as solvent instead of water. Thus the water system:

\[
\text{MOH} + \text{HX} \quad \text{neutralisation} \quad \text{MX} + \text{HOH} \\
\text{aqo} \quad \text{aqo} \quad \text{hydrolysis} \quad \text{aqo} \\
\text{base} \quad \text{acid} \quad \text{base} \quad \text{acid}
\]

and in the ammonia system:

\[
\text{M.NH}_2 + \text{HX} \quad \text{neutralisation} \quad \text{MX} + \text{H.NH}_2 \\
\text{ammonio} \quad \text{ammonio} \\
\text{ammonio} \quad \text{ammonio} \\
\text{base} \quad \text{acid} \\
\text{acid} \\
\text{salt} \quad \text{salt}
\]

Ref: Hackh’s Dicz (1944), 355-R (Franklin E.C.) & 46-L (Ammonia system)

Franklin Institute (FI). An American scientific establishment founded in 1824 in Philadelphia, Pennsylvania and located at 20th & Benjamin Franklin Parkway. Devoted to Science and Mechanical Arts, it has published since 1826 the Journal of the Franklin Institute, while since 1968 it publishes the monthly newsletter “Explosives and Pyrotechnics”, edited by Mr Gunther Cohn.

The main division of the Institute is the “Franklin Institute Research Laboratory” (FIRL), one of the Amer top ten not-for-profit laboratories. It performs research & development tests and engineering in the basic and applied sciences; also engages in educational activities in the physical and biological sciences. It applies technical expertise to the solution of current problems for government and industry. FIRL employs 250 full-time professional engineers and scientists and handles more than six million dollars in contracts annually. Major departments of FIRL are: Electrical Engineering, Materials and Physical Sciences, Mechanical and Nuclear Engineering, Science Information Services, and Systems Science. In the science of explosives, FIRL has an international reputation for evaluating electroexplosive devices, hazards analysis, and technical information.

It should be noted that FIRL’s sponsors “Symposiums on Explosives and Pyrotechnics” and that the Eighth Symposium was held in Los Angeles, Calif on Feb 5-7, 1974

Note. Proceedings of past Franklin symposiums summarize the state of the art on
explosives and related topics. Meetings were attended by about 300 representatives from government and industry and each resulted in about 50 papers. Proceedings are available from DDC (Defense Documentation Center, Cameron Station, Alexandria, Va 22314) or NTIS (National Technical Information Service, US Dept of Commerce, Springfield, Va 22151) as follows:

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<td></td>
<td>Oct 63</td>
<td>AD-440764</td>
<td>DDC</td>
</tr>
<tr>
<td>5</td>
<td>Jun 67</td>
<td>AD-720454</td>
<td>NTIS</td>
</tr>
<tr>
<td>6</td>
<td>Jul 69(U)</td>
<td>AD-514256</td>
<td>DDC</td>
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<tr>
<td></td>
<td>Jul 69</td>
<td>AD-720455</td>
<td>NTIS</td>
</tr>
<tr>
<td>7</td>
<td>Sep 71</td>
<td>AD-742150</td>
<td>NTIS</td>
</tr>
</tbody>
</table>

FIRL also sponsors periodically conducted popular courses on Pyrotechnics and Explosives. Prof J.H. McLain, President of Washington College, Chestertown, Maryland and Mr Gunther Cohn, Senior Staff Engineer of the FIRL, Engr of the (APL) Applied Physics Laboratory are the principal lecturers.

The following other activities are part of the Franklin Institute: Library, Science Museum, Planerium, Journal, Medal Awards, Bartol Research Foundation and Institute Education

**Ref:** 1) The Franklin Institute Research Laboratories Brochure (Aug 1972)
2) Gunther Cohn of Franklin Institute (Oct 1973)

**Franklin's Method of Electric Initiation.** It is not generally known but Benjamin Franklin invented electric initiation. He wrote, in a letter to Peter Collinson, "I have not heard that any of your European electricians have ever been able to fire gunpowder by the electric flame. We do it here in this manner. A small cartridge is filled with dry powder, hard rammed, so as to bruise some of the grains; two pointed wires are then thrust in, one at each end, the points approaching each other in the middle of the cartridge till within the distance of half an inch; then, the cartridge being placed in the circuit, when the four jars are discharged, the electric flame leaping from the point of one wire to the point of the other, within the cartridge against the powder, fires it, and the explosion of the powder is at the same instant with the crack of the discharge"

**Ref:** G. Cohn, Explos&Pyrots 6(7), 1973

**Frontsuzkaya Smes'.** Rus for French Mixture, which consisted of PA (Picric Acid) 80 & DNN (Dinitronaphthalene) 20%. It was used for filling some shells, aerial bombs, anti-tank mines and for demolition charges known as "podryvnyye shaski" of the same size as those filled with Trotyl (TNT)

5) Gorst (1972), not listed

**Front’s Explosive.** It contains Diazodinitrophenol 20, Tetracene 5, Pb ethylenedinitramine 25; Ca silicide 20, Ba nitrate 24, Pb peroxide 6 & gum arabic 0.05% in water as binder. It was proposed for use in perforating petroleum wells. Its expln temp is
above 300° and it is not too sensitive to impact and friction. Its power is moderate.
Refs: 1) A.O. Franz, USP 2708623 (1955)
2) Giua, Trattato VI (1959), 405

Frary's Metal. An alloy of lead with small amounts of Ba and Ca. It was prepared by electrolytic deposition of Ba & Ca in molten lead. It was as hard as Pb-Sb alloys. Used during WWI for shrapnel bullets.
Ref: Hackh's Dict (1944), 355-R

"FRAS". British thickened fuel described under Gel-gas

Fraser & Collaghan patented in Australia at the end of the 19th century Dynamites under the name of Kallenites, being absorbents dried and pulverized leaves and bark of eucalyptus trees. Some varieties contd salt-peter and NC. Trials conducted in 1899 in quarries of Glebe Island gave excellent results. It was found that these Dynamites do not evolve on explosion toxic gases and are, for this reason, particularly suitable for underground work.
Ref: Daniel, Dict (1902), 310 & 390

Freeness (or Wetness) and Its Testing.
Hackh's Dict (1944), p 357-L defines "freeness" as the extent to which a pulp for the manuf of paper has not been hydrated by beating. Accdg to J.N. Stephenson, Ed, "Preparation and Treatment of Wood Pulp", McGraw-Hill, NY, Vol 1 (1950), pp 943-56, the "freeness" (slowness, or wetness) is the quality of pulp stock that determines the rate at which it parts with water when being formed into a sheet on a wire screen or perforated plate. The freeness test gives information regarding the drainage behavior to be expected on the paper machine, and it also gives some indication of the strength, bulk and finish of the final paper.

The following freeness testers are described in the above book:

a) Canadian Standard Freeness Tester (pp 942-951);
b) Schopper-Riegler Freeness (Slowness) Tester (pp 951-56)
c) Williams Precision Freeness Tester (pp 955-56)
d) Drainage Tester (pp 956-57)
e) British Drainage Tester (pp 957-60)

According to L. Sheldon, PB Rept 12662 (1945) the Germans used the Schopper-Riegler Device for testing the crepe paper used for the manufacture of nitrocellulose.

Free Radical and Free Radical Propellants.
Accdg to Hackh's (Ref 1), a free radical is an org compd in which all the valences are not satisfied; hence, an unsaturated molecule, as:

\[ \text{2Ph}_3\text{C} \rightleftharpoons \text{Ph}_3\text{C} - \text{CPh}_3 \]

triphenylmethyl from hexaphenylethane;

\[ \text{2Ph}_2\text{N} \rightleftharpoons \text{Ph}_2\text{N} - \text{NPh}_2 \]
diphenyl nitrogen from tetrphenylhydrazine.

In a strict sense also:

\[ 2\text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4 \]
nitrogen peroxide from dinitrogen tetroxide.

Free radicals may also be defined as "unstable fragments of organic compounds". Small free radicals exist in flames and in many high-speed chem reactions. Generally they last for only millionths of a second before combining violently with each other.

Free radicals are of particular interest in rocket propulsion, since their presence in chemical fuels might give rockets much higher thrust (thru the increased momentum discharge) than do conventional chem fuels, if economical ways can be found to generate and use them (Ref 3).

Accdg to Boehm (Ref 2), the upper reaches of the atmosphere where matter is extremely sparse, are relatively rich in free radicals, in that region, chiefly atomic forms of hydrogen, nitrogen and oxygen are present. Conceivably, a ramjet satellite flying a hundred miles or more above the earth could scoop up free radicals and use them as fuel. A scoop 30-feet in diam could collect enough radicals to generate about 1 watt of power - enough perhaps to effect the drag in the atmosphere and keep a satellite in its orbit indefinitely.
It may be possible to stabilize the free radicals at sea-level and feed them directly into rocket engine. In 1954, two scientists at the Natl Bur of Standards Labs sent a stream of nitrogen thru an electric discharge and immediately froze it at −452°F. A small fraction of a percent of the frozen material was atomic nitrogen as free radical. The potential propulsive power of free radicals is astonishing. A fuel consisting of 10% H and 90% H₂ would be more powerful than any known liquid chemical propellant; and pure H atoms reacting with each other to form H₂ would theoretically produce a specific impulse of 1800 — twice that of nuclear rocket engine
Refs: 1) Hackh’s Dict (1944), 357-L

Free Rocket. A rocket having fixed fins, but no control surface, that is, no provision for guidance
Ref: Glossary of Ordn (1959), 123-L

Free Run. As applied to guns, the travel of a projectile from its original position in the gun chamber until it engages with the rifling of the bore
Ref: Glossary of Ordn (1959), 123-R

Free Surface. See Vol 4, p D349-L


Freezing of Dynamites and Antifreezes. See under DYNAMITE in Vol 5, pp D1588-R to D1593-L

Freezing (or Frigorific) Mixture or Cooling Bath. A mixture of substances that absorbs heat and thus lowers its temperature or that of its immediate surroundings. Used in analytical and synthetic chemistry for reactions at low temperatures. Following are aqueous mixtures listed in Ref 1:
a) 1 pt NH₄NO₃+1 pt Na₂CO₃+1 pt H₂O lowers to −20°C
b) 5 pts NH₄Cl+10 pts powdered ice or snow gives −5° to −18°
c) 5 pts NaCl+5 pts NH₄NO₃+12 pts ice or snow gives −15° to −25°
d) 3 pts CaCl₂+1 pt ice or snow gives −40° to −70°
e) 10 pts dil H₂SO₄+8 pts ice or snow gives −65° to −90°

A more complete list of aqueous freezing mixtures is given in Ref 2

The following non-aqueous cooling baths are listed in Ref 2:
a) Alcohol—carbon dioxide gives −72°
b) Ammonia, boiling point −33°
c) Chloroform—carbon dioxide gives −77°
d) Ether—carbon dioxide gives ca −78°
e) Liquid air, bp −190°
f) Liquid nitrogen, bp −196°
g) Liquid oxygen, bp −183°
Refs: 1) Hackh’s Dict (1944), 357-R
2) Lange’s Hdb (1961), 1191
Freezing (Solidification, Congelation or Setting) Point (fr p) and Its Determination. Freezing point is the temperature at which a liquid or solution solidifies. It is the temperature at which the liquid and solid states of a substance are in equilibrium at a given pressure (usually atmospheric). The second definition may be applied to Melting (or Freezing) Point, which may also be defined as the temperature at which a solid changes to a liquid. For pure crystalline substances, mp is usually identical with fr p, while for many mixtures, they are not identical. For example, fats and waxes do not solidify until they have been cooled several degrees below their mp's. If a liquid be cooled under pressure the fr p rises if the solid is of higher specific gravity than the liquid; if it is of lower specific gravity, as in the case of water, the fr p is lowered. Since the fr p varies slightly with pressure, the pressure should be stated in reporting a freezing point. However, atmospheric pressure is commonly understood unless otherwise stated.

The simplest method for freezing (setting) point determination is one employing an evaporating dish. This method was commonly used in US Ordnance Works during WWII for rapid determination of freezing point of TNT. It is described in Ref 1, Chap V, p 3. In the laboratory of Keystone OW, Meadville, PA, the dish was replaced by Pyrex custard cup because it was more convenient to handle. The cup procedure described in Ref 2 and in Vol 2, of Encycl, p C7-L was used for calibration of thermometers by using liquids of known freezing points, or for detm of frp's of unknown liquids, using calibrated thermometers. Another simple method employed a Pyrex cylinder, thermometer, and a stirrer with a ring surrounding the thermometer. This method is described in Vol 2, p C6-R. More complicated apparatus is shown in Fig on p A613-L of Vol 1. It has been used in Sodium Azide Laboratory but can be used for many other compounds.

Finally, the best and more precise apparatus is that shown in Fig on p D1473-R of Vol 5. It has been used for determination of setting point of diphenylphthalate. It is a copy of apparatus described in Ref 1, Chap V, p 5, which is a modified version of US Joint Army-Navy Specification JAN-T-248 for TNT (Compare with Melting Point).


Freiberg (Poudre de mine de). A French mining explosive, claimed to be economical to use: Na nitrate 61.65, sulfur 17.25 & charcoal 17.35% Ref: Daniel (1902), 310

Freins de bouche. Fr for Muzzle brakes

Freins de tir. Fr for Recoil brakes

French Ammonials S and C. See Vol 1, p A290 (Table), under AMMONAL

French Ammonium Nitrate Gelatin Dynamites. See Vol 1, p A368 (Table), under AMMONIUM NITRATE GELATIN

French Ammunition and Explosives of WWII. The principal types were HE Service Bombs, which were made of hardened steel, forged or
<table>
<thead>
<tr>
<th>Designation and Type</th>
<th>Overall Length</th>
<th>Max. Diameter</th>
<th>Type of Filling</th>
<th>Wt of Filling</th>
<th>Total Wt</th>
<th>Fuze</th>
</tr>
</thead>
<tbody>
<tr>
<td>14kg AP (Naval)</td>
<td></td>
<td>3¾</td>
<td>PA &amp; TNT</td>
<td>1½ lb</td>
<td>31 lb</td>
<td></td>
</tr>
<tr>
<td>73kg Type G2, Antisubmarine</td>
<td></td>
<td>8.66</td>
<td>TNT</td>
<td>106</td>
<td>160</td>
<td>Nose No 1, Tail No 8</td>
</tr>
<tr>
<td>150kg Type 12, Antisubmarine</td>
<td></td>
<td>14</td>
<td>TNT</td>
<td>224</td>
<td>330</td>
<td>Same as above</td>
</tr>
<tr>
<td>224kg Type K (Naval)</td>
<td></td>
<td>14.75</td>
<td>PA or PA + TNT</td>
<td>240</td>
<td>490</td>
<td>Nose No 10, Tail No 8</td>
</tr>
<tr>
<td>222kg Model 1938 AP (Naval)</td>
<td></td>
<td>10¾</td>
<td>PA + TNT</td>
<td>50</td>
<td>500</td>
<td>Tail No 7</td>
</tr>
<tr>
<td>410kg Type L-AP (Naval)</td>
<td></td>
<td>15¾</td>
<td>PA or PA + TNT</td>
<td>265</td>
<td>900</td>
<td>Nose No 9, Tail No 8</td>
</tr>
<tr>
<td>438kg Model 1938 AP (Naval)</td>
<td></td>
<td>11.9</td>
<td>PA</td>
<td>24</td>
<td>1000</td>
<td>Tail No 7</td>
</tr>
<tr>
<td>720kg Type M (Naval)</td>
<td></td>
<td>20.5</td>
<td>TNT</td>
<td>860</td>
<td>1600</td>
<td>Nose No 11, Tail No 8</td>
</tr>
<tr>
<td>125kg GP-HE (Naval)</td>
<td>61.5''</td>
<td>12.2</td>
<td>TNT</td>
<td>Unknown</td>
<td>12.5</td>
<td>Nose only</td>
</tr>
<tr>
<td>10kg (PA) Antipersonnel Type I and II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50kg (A) GP-HE</td>
<td>39.0</td>
<td>6.15</td>
<td>MDn</td>
<td>22.0</td>
<td>88.0</td>
<td>Nose Type H, Tail – 3B15</td>
</tr>
<tr>
<td>50kg (GA MMn) GP-HE</td>
<td>46.5</td>
<td>7.85</td>
<td>MMn</td>
<td>63.0</td>
<td>112.0</td>
<td>Tail M No 2</td>
</tr>
<tr>
<td>50kg (DT No 1) GP-HE</td>
<td>46.5</td>
<td>8.25</td>
<td>MDn or DD 60/40</td>
<td>44.0</td>
<td>123.0</td>
<td>Tail 3B15</td>
</tr>
<tr>
<td>50kg (DT No 2) GP-HE</td>
<td>46.5</td>
<td>7.7</td>
<td>Same</td>
<td>42.0</td>
<td>123.0</td>
<td>Same</td>
</tr>
<tr>
<td>50kg (DT No 3) GP-HE</td>
<td>46.5</td>
<td>7.86</td>
<td>Same</td>
<td>44.0</td>
<td>123.0</td>
<td>Same</td>
</tr>
<tr>
<td>100kg GP-HE</td>
<td>56.0</td>
<td>10.8</td>
<td>Same</td>
<td>258</td>
<td>Unknown</td>
<td>Nose &amp; Tail</td>
</tr>
<tr>
<td>200kg GP-HE</td>
<td>62.0</td>
<td>14.5</td>
<td>Same</td>
<td>503</td>
<td>Unknown</td>
<td>Nose &amp; Tail</td>
</tr>
<tr>
<td>500kg Model 1930 GP-HE</td>
<td>84.0</td>
<td>19.3</td>
<td>Same</td>
<td>600</td>
<td>1285</td>
<td>Nose &amp; Tail</td>
</tr>
<tr>
<td>500kg No 1 GP-HE</td>
<td>83.0</td>
<td>21.4</td>
<td>Same</td>
<td>662</td>
<td>1182</td>
<td>Same</td>
</tr>
<tr>
<td>500kg No 2 GP-HE</td>
<td>79.0</td>
<td>19.6</td>
<td>Same</td>
<td>595</td>
<td>1148</td>
<td>Same</td>
</tr>
<tr>
<td>40kg Fragmentation Bomb</td>
<td>37.75</td>
<td>6.25</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Nose No 3, Tail, unknown</td>
</tr>
<tr>
<td>1 kg Incendiary Type A</td>
<td>14.5</td>
<td>Unknown</td>
<td>Thermite</td>
<td>Unknown</td>
<td>1 kg</td>
<td>Nose only</td>
</tr>
<tr>
<td>10 kg (Model 1927) Incendiary</td>
<td>22.1</td>
<td>3.54</td>
<td>Mg Incendiary</td>
<td>Unknown</td>
<td>8 kg</td>
<td>Nose only</td>
</tr>
<tr>
<td>Smoke Bomb</td>
<td>9.45</td>
<td>2.75</td>
<td>Titanium Tetra-chloride</td>
<td>100 ml</td>
<td>Unknown</td>
<td>None</td>
</tr>
</tbody>
</table>
drawn. The service HE bombs of the old pattern were painted grey, while the new pattern were painted yellow. The Incendiary Service Bombs of the new pattern have a red body and a green tail, and the Smoke Service Bombs, a black nose, green body and tail. There were also Practice Bombs, Instruction Bombs and Ballast Bombs. The hardened steel bombs were usually filled with MMn, the steel bombs with MDn and other bombs with DD 60/40.

Most of the Naval HE bombs were filled with Mélinite, Mélinite plus Tolite or Tolite alone. The incendiary bombs usually contained thermite or magnesium incendiary mixture, and some smoke bombs contained a titanium tetra-chloride mixture.

Table F14 lists bombs described in Ref, pp 177-87

Abbreviations: AP - Armor-piercing; DD 60/40 - PA/DN-Phenol; DNN - Dinitoraphlene; GP - General Purpose; HE - High Explosive; MDn = DNN/PA-20/80%; Mélinite-(PA) - Picric Acid; MMn = MNN/PA-30/70%; MNN - Mononitronaphthalene; Tolite - (TNT)-Trinitrotoluene

Note: French weapons of WWII are listed in Table F19

Refs: 1) Anon, "Italian and French Explosive Ordnance", OP 1668 (1946), pp 177-87
2) Anon, "Italian and French Explosive Ordnance", TM9-1985-6/TO 39B-1A-8 (1953), 177ff

French Anarchist's Explosive, known as Green Powder, used in bombs of revolutionists during 1892's criminal assaults, contd:
K chlorine 49, K ferrocyanate 28 & sugar 23%. This expl mixt, belonging to Cheddite-class, was very sensitive and dangerous to handle


French Armor. After WWII, France concentrated on light armored vehicles and did not try to design and develop a complete armored system. Battle tank regiments used American Patton tanks. Since 1950, stress was laid on mobility and a light air transportable tank was designed. This led to development of the AMX 13-ton tank. Present inventory includes personnel carriers, command vehicles, self-propelled howitzers, special purpose engineer vehicles and recovery vehicles.

The following paragraphs describe basic features of this inventory:

AMX 13-ton Tank. Tank's loaded weight is 14³⁄₄ metric tons, road speed 37mph. Its range is 150 miles or 13 hours. Tank is 7 feet, 6 inches in height and its main weapon is a 75mm gun with automatic reloading mechanism. Tank fires HE armor-piercing shells with muzzle velocity of 3280fps. A 7.5mm coaxial machine gun and four smoke-shell projectors complete the armament.

AMX-SS-I Tank. Some AMX tanks have been equipped with four SS-II antitank missiles mounted in fire position in front of turret. Missiles are made by NORD Aviation, weigh 62.7 lbs and carry a shaped charge. Maximum range is 11480 ft and can be reached in 22 sec. Missiles are wire guided.

AMX Personnel Carrier Vehicle weighs 13½ tons and has same technical features and performance as its parent tank. It can carry 12 men plus a driver. Onboard armament consists of 7.5mm machine gun in a 360° turret. It is convertible to a command vehicle, ambulance, or cargo vehicle with 3-ton carrying capacity.

AMX 105mm Self-propelled Howitzer. Built on AMX chassis and has same performance. Its range is 9 miles. It is also equipped with anti-aircraft machine gun and a machine gun for close defense. It weighs 16 tons combat loaded with a 5-man crew and fifty-four 105mm rounds on board.

155mm Self-propelled Howitzer. Mounted on a self-propelled AMX carriage, this howitzer has a range of 12.4 miles, loaded weight is 17 metric tons.

30mm Self-propelled Double-Barreled Gun. An AMX chassis carries a turret equipped with two 30mm guns which fire HE or armor-piercing projectiles at a muzzle velocity of 3280fps. Max range 8200 ft and rate of fire
is 20 rounds/sec. Also has "Black-Eye" surveillance radar. Vehicle weighs 16 metric tons combat loaded with crew of a driver and two turret gunners.

**AMX Recovery Vehicle.** Same technical features as in AMX tank, weighs 14 1/2 metric tons; has 3 man crew, a generator, winch with a tractive power of 15 tons and a crane to lift 5 metric tons.

**Engineer Combat Vehicle.** Can transport an engineer squad and its equipment. Used to clear roads and lay down various obstacles. Crew consists of a driver, machine gunner, a non-commissioned officer and seven soldiers. Has a mechanical shovel, winch and a crane with a 5 ton lifting capability. Armament is a 12.7mm machine gun. A 3-ton trailer carries all materials needed for its mission.

**Light Bridge-Laying Tank.** Built on AMX chassis, can transport and lay a bridge of 25 ton class. Has a 3-man crew.

Other armored vehicles include: the Armored Reconnaissance Vehicle (EBR), Light Armored Combat Car and the new AMX 30-Ton Tank.

Rej: Service d'Information, d'Études et de Cinematographie, Ministère des Armées, France, Ordru 50, No 273, pp 291-95 (1965)

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**French Commercial Explosives of Non-Permissible Type.** See Vol 3, p C438. Included as of 1966 were: Explosifs antigrisesouteux; Explosifs chloratés ou Explosifs du Type OC, also known as Cheddires; Explosifs nitratés ou Explosifs du type N; Explosifs nitratés à la pentolite; Explosifs nitratés à l'aluminium; Explosifs nitratés résistant à l'eau; Explosifs plastiques; Sevrane n° 1, Sevrane n° 2; Sofranex A and Tolamite.

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**French Compound.** A substance of unknown composition obtained when dilute nitric acid reacts with a mixture of TNT and lead (or iron). French Compound easily ignites when brought into contact with nitric acid vapor at 100°. Either fragmentation or HE bombs can be loaded with this material and the method of loading is either lump or by compression of powdery material. This material was used by Russians. Compare with French Mixture.

Rej: Aberdeen Proving Ground, "Allied and Enemy Explosives" (1946)

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**French Cyclonite, known as Hexogène.** See Vol 3, p C615-L, under CYCLOTRIMETHYL-ENETRINITRAMINE

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**French Cyclonite Binary and Ternary Mixtures.** See Vol 3, p C626-R. Included as of 1966 were the following: Hexogène/cire d'abeille (RDX & beeswax), Hexolite or HT (Hexogène-Tolite) (RDX–TNT); Sevrane n° 1; Explosif plastique PE1; Explosif plastique PE3A; Explosif plastique TG; and Explosif plastique TN

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**FRENCH DYNAMITES.** Accdg to Pascal (Ref 1), Vennin, Buret & Lécorcheré (Ref 2), and Pepin Lehalleur (Ref 3), the French Dynamites of before WWII were divided into:

A: Dynamites à absorbant inerte, which are subdivided into Dynamite n° 1 – NG 75 & kieselguhr 25%; Dynamite n° 2 – NG 35 &
French Gelatin Dynamites can be subdivided into the following categories (Ref 2, p 553)

Ca) Dynamites-gommes. They contained large amounts of NG, and small amounts of CC. Those containing 70 to 83% NG and small amount of CC contained other ingredients, as can be seen in Table F15

Cb) Dynamites gélatinées. They contained smaller amounts of NG, slightly smaller amounts of CC, but larger amount of K nitrate. Two formulations are listed in Table F16

<table>
<thead>
<tr>
<th>Components</th>
<th>Gomme A</th>
<th>Gomme B</th>
<th>Gomme C</th>
<th>Gomme D</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>92-93</td>
<td>83</td>
<td>70</td>
<td>49</td>
</tr>
<tr>
<td>CC</td>
<td>8-7</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K nitrate</td>
<td>-</td>
<td>9</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>Cellulose</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>-</td>
<td>-</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Woodmeal</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

Note 1: Accdg to Davis (Ref 4, p 346), Gomme A was also known as Dynamite-gomme-extra-forte and Gomme B as Dynamite-gomme-potasse; if K nitrate was replaced by Na nitrate the name became Dynamite-gomme-soude

Note 2: Compn of low-freezing Gomme B is given in Table 1, in Vol 5, p D1591, under DYNAMITE, Historical

Note 3: Compn of Gomme E is taken from Ref 4, p 346

<table>
<thead>
<tr>
<th>Components</th>
<th>Gélatinée n° 1</th>
<th>Gélignite A</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>57</td>
<td>65</td>
</tr>
<tr>
<td>CC</td>
<td>3</td>
<td>3.8</td>
</tr>
<tr>
<td>K nitrate</td>
<td>34</td>
<td>23.5</td>
</tr>
<tr>
<td>Woodmeal</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Cellulose</td>
<td>-</td>
<td>7.5</td>
</tr>
<tr>
<td>Ocher</td>
<td>-</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Davis (Ref 4, p 346) gives among the French Gelatin Dynamites, the compns listed here in Table F17
Note: Fr low-freezing Gelatine is listed in Table 1, under DYNAMITE, Vol 5, p D1591
Pepin Lehalleur (Ref 3) lists on p 334 the Gomme BAM which is one of the permissible Gelatins: NG 60, CC 3, AN 31 & cellulose 6% and on p 335 he lists a non-permissible Gelatin which contains NG 57, CC 3, alkali nitrate 34, woodmeal 4, flour 1.8 & ochre 0.2%
Pepin Lehalleur also lists the following Gommes inconvétables (Nonfreezing Gelatins): 1) Manuf by the Nobel Française: NG 75, CC 5, alkali nitrate 10, DNT 8 & woodmeal 2%; and 2) Manuf by the Société d’Explosifs et de Produits Chimiques: NG 66.4, NGc 16.6, CC 5, alkali nitrate 10 & woodmeal 2% (Ref 3, p 336)
Note: Vennin et al (Ref 2, p 557) use the term “antigel” instead of “inconvétable”
Two low-freezing Verge Dynamites are listed in Table 1, under DYNAMITE in Vol 5, p D1591
Cc) Dynamites à faible taux de nitroglycérine qui se présent sous forme pulvérulente. To this group belong powdery Dynamites with NG content below 30% and CC content 0.5–1.0%. Those which are “permissible” are known as “Explosifs antigrisou,” “Grisou-nitrate” and “Grisoutines.” The meanings of these terms as well as of Belgian term “Explosifs SGP” are explained in Vol 1 of Encycl, p A466-R

Vennin, Burlot & Lécorché (Ref 2), listed on p 557, under the name Grisou-dynamite-couche-salpèttrée (antigel), the following compn: NG 9.6, NGc 2.4, CC 0.5, AN 82.5 & K nitrate 5%. A similar compn, but without NGc, is listed by them in Table on p 554, together with Grisou-dynamite-couche and Grisou-dynamite-roche. These three compns were listed in Vol 1 (Ref 7), Table on p A467-L, entitled "Antigrisou (Explosifs)"

Vennin et al also listed on p 554 as permisibles: Lignamite-couche (or Grisel-lite-couche), Martinite and Tolamite. Tolamite was described in Vol 3 of Encycl (Ref 7) on p C437-R, under nonpermisibles, while Lignamite and Martinite will be listed here under L & M

Davis (Ref 4) listed in Table on p 351, four “Grisou-dynamites” of the same compn as given by Vennin et al (Ref 2, p p 554 & 557), of which one compn, Grisou-dynamite-roche-salpêtrée: NG 29.0, CC 1.0, AN 65.0 & K nitrate 5%, was not listed in Vol 1, p A467-L
One of the Fr low-freezing Grisou-dynamites is listed in Table 1, under DYNAMITE, Historical in Vol 5, p D1591
Some “antigrisou” expls contained no NG. A brief list of such “substitut” Dynamites is given in Vol 1, p A466-R (Ref 7)
Pepin Lehalleur (Ref 3) lists on p 342 three Dynamites manufd at Cugny. These expls are listed in Vol 1 of Encycl, p A356, under the names of French 1, 2 & 3. Pepin Lehalleur also lists a similar Dynamite manufd by the Société Nobel. This expl will be described in this section under Nobelites
The following “types réglementaires en France pour les travaux dans les mines grisouteuses” (before WWII) were listed by Pepin Lehalleur (Ref 3, p 343) (See Table F18)

Table F18

<table>
<thead>
<tr>
<th>Components</th>
<th>Grisou-dynamite</th>
<th>Antigrisou</th>
<th>Antigrisou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorure de nitrèt</td>
<td>16.0</td>
<td>29.1</td>
<td>11.7</td>
</tr>
<tr>
<td>NG</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NGc</td>
<td>0.5</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>CC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K nitrate</td>
<td>55.0</td>
<td>70.0</td>
<td>88.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na chloride</td>
<td>22.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vivas, Feingspan & Ladreda (Ref 5), listed on pp 390, 391, 395 & 396 several French Dynamites of practically the same compn as those given in French books listed here as Refs 1, 2 & 3
The following “nonpermissible” Dynamites are listed in Vol 3 of Encycl (Ref 8, p C438). They are described by Médard (Ref 6, p 209–19). He subdivided them as: Explosifs chloratés
ou Explosifs du type OC, Explosifs nitrés à l'aluminium; Explosifs nitrés résistant à l'eau; Explosifs plastiques; Searinite No 1; Searinite No 2; Sofranex A; and Tolamite.

The following "permisible" Dynamites are listed in Ref 8, pp C450 & C451, accdg to classification of Mépard (Ref 6, pp 219–22): Grisou-dynamite chlorurée no 1 (1932); Explosif du type N, no 7 (of Burlot & Schwob); Explosif du type N no 9 (of Audibert)(1938); Grisou-dynamite chlorurée no 14 (1948); Grisou-dynamite chlorurée no 15 (1949); Explosif du type N no 62 (of Mépard); CSE (Commission des Substances Explosives) Explosifs, such as Explosif 123–CSE–1948; Explosif 136–CSE–1948; and Explosif 68–CSE–1949.


FRENCH DYNAMITES AND THEIR SUBSTITUTES.

Following exp1 comps, many of them obsolete, are described in Vols 1, 2, 3 and in Vol 5 under DYNAMITES AND THEIR SUBSTITUTES: Aluminum Containing Dynamites, Amido ou Explosif amylacé, Ammonique Dynamite, Ammonite, Anagon, Antigrisou no 1, no 2 A no 3; Antigrisou II, Antigrisou-couche, Antigrisou-couche salpêtrée, Antigrisou-couche, Antigrisoutex explosives N no 7, N no 9 & N 62 (See Vol 1, p A466 & A467), Antigrisoutines, Bayon, Bender, Bengaline, Berclavite, Bergé, Berthelot, Berthollet, Blanche dynamite de Diller, Blanche dynamite de Paulilles, Boritines de Turpin, Borlinetto, "C" (Explosifs), Carbite, Carbazotine, Carbonites (French Modifications), Carrière, Casthelaz et Désignolle, Castro, Catactine, Cauvel et Baron, Cellamite, Charbonneux, Chauvet, Cheddites, Colombia (or Columbia), Comil ou Poudre blanche, Cotter, Césylités, CSE (Explosifs), Cugnité, "DD" (Explosif de), DeCastro, Defrangeur, Delattre, Delorbe, Désignolle, Delorbe, Demorgue, Duplexite de Turpin, Dynamite gélatinée, Dynamite-grisoute, Dynamite "O", Dynamite de Vonges, Dynamogène, Dynamotive et Dynastite Explosifs antigrisouteux, Explosif "N", Explosifs "N", "NDNT", "NO", "N4", "NT", "NTN", "N2TN" and "NX"; Explosif "O", Explosif "93" (or Prométhée), Explosif "P", Explosif "S", Explosifs de sûreté, Explosif type C, Explosif type N, Fahm, Favier, Fenices, Fielder, Fluorite, Fontaine, Forcites, Fortex, Gélatinée no 1 (See Table 11), Gélatines A & B (See Table 12), Gélinites (See Tables 11 & 12), Gommes A, B & C (See Table 10), Gomme BAM (See under Table 12), Gomme E (See Table 12), Gommes inconégables (See under Gomme BAM); Grisou-dynamite-couche, Grisou-dynamite-couche-salpêtre et Grisou-dynamite-roche are described in Vol 1, p A467–R as Antigrisou (Explosifs).

The following French Dynamites are described, together with expls of other nations, in this list under the letters G, etc.: Grisou-naphthalite-couche, Grisou-naphthalite-roche.

French Explosive Industry of After WWII was reviewed by LeRoux in Revue de l'Industrie Minérale 33, 276–84 (1952).

French Explosives. See under Explosifs in this Vol and under individual names, such as: Anilite, Chedditte, Favier explosifs, Grisou-dynamites, Hexogène, Mélinite (PA), Nitramidon (NS), Poudre noire (BkPdr), Schneiderite, Tolite or Troyt (TNT) and others.

French Gelatinized Explosives (called Gomme, Dynamite-gomme, Gelatine). Expls resembling in their compositions American Blasting Gelatin (called in France, Dynamite-gomme-extra forte), Gelatin Dynamos or British Gelignites
Refs: 1) Marshall T(1917), 372 2) Encycl., Vol 5(1972), Table 1, p D1591

French Grisou-Dynamite. See under DYNAMITE in Vol 5, p D1591, Table 1, last column

French Ground-to-Ground Strategic Ballistic Missile, abbr as SSBS (Sol-Sol-Ballistique-Stratégique) is an ICBM type weapon described in Ref
Ref: Anon, Ordre 48, 490(1964)

French Lead Block (or Trauzl) Test. See Coefficient d’utilisation pratique (CUP) in Vol 3 and on pp IX-X in Vol 1 of Encycl
Addn Ref: L. Médard, MAF 33, 337–388(1959)

French Mixture (Frantsuzskaya Smes’, in Russian). Mixture of PA (Picric Acid) 80 & DNN (Dinitronaphthalene) 20%, which may be considered as phlegmatized PA (Refs. 1, 3, 4 & 5). It was used both in France and in Russia as a bursting charge in mines, bombs and shells. A slightly less sensitive and less powerful mixture was Russkaya Smes’ (Russian Mixture)(Ref.4), called Russki Sipav (Russian Splav) in Refs. 1 & 3. It consisted of PA 51.5 & DNN 48.5%. The name Russkaya Smes’ was given by Blinov (Ref. 2) to a mixture of AN 50, TNT 38 & TNN 12%. French Mixture was used by the Russians for loading medium caliber shells (larger than 76.2mm) as late as WW II
Refs: 1) Shilling(1946), 102 (Frantsuzskaya Smes’); 90 (Russkii Splav) 2) Blinov, Vol 2(1949), 64–5 (Russkaya Smes’) 3) Fedoroff et al, PATR 2145(1955), p Rus 6-R (Frantsuzskaya Smes’); p Rus 20-R (Russkii Splav) 4) Gorst (1957), 99 (Frantsuzskaya Smes’); 99 (Russkaya Smes’) 5) Gorst (1972), 136 (Mixture of PA 80 & DNN 20%, w/o naming it Frantsuzskaya Smes’)

French Low-Freezing Dynamites are expls having comps similar to Amer low-freezing Dynamites, such as for example: NG 66.4, EGDN 16.6, Colloid Cotton 5.0, K nitrate 10.0 & woodmeal 2.0% (Ref 1). Two Fr low-freezing gelatins are listed in Ref 2
Refs: 1) Marshall T(1917), 373 2) Encycl of Explosives, PATR 2700, Vol 5(1972), p D1591, Table 1

French Military Explosives, Requirements.
Acctg to Pepin Lehalleur (Ref 1, pp 53–6) the following requirements were specified for explosifs militaires:
1) Great power and brisance in relation to volume of explosive, which means great density of loading
2) True and complete detonation by an initiator even at atmospheric pressure and without tampering
3) Insensibility to shock or discharge of expl loaded in a projectile and insensibility to impact of a bullet
4) Inalterability by heat, moisture and contact with the walls of container (shell). Inoxibility by air or on contact with oxidizers
5) Constancy of properties and absence of exudation
6) For expls used by sappers in military mines, no poisonous gases, such as CO, should be produced on detonation
7) Facility of producing explosives from domestic materials and domestic factories

The following explosives were used before WWII by the French for military purposes:
Trotyl (TNT), Mélinite (Trinitrophenol or Picric Acid), Dynamite gomme (NG/CP 2–92/8), Penthrite (PETN or Pentaerythritol Tetranitrate) and Hexogène (RDX or Cyclonite). Their properties are listed in Table, p 54 of Ref 1
Explosives used by the French during WWII are given in Ref 2
Refs: 1) Pepin Lehalleur (1935), pp 53–56 2) Anon, “Italian and French Explosive Ord-
French Safety Explosives (Explosifs de sûreté). Strictly speaking, this term should be confined to explosives safe to handle and to transport (corresponding to German term "Handhabungssichere"), but sometimes the term was used in regard to explosives "safe to use in gaseous coal mines". The latter explosives are known now as explosifs antigrisouteux, which correspond to German "Schlagwettersichere", Permissible Explosives" in USA) or "Permitted Explosives" in Great Britain (Ref 1, p 582 & Ref 4, p C450-R)

Accdg to Vennin, Burtol & Lécorché (Ref 2, p 212) the main requirement for "explosifs de sûreté" is insensitivity to friction and only low (if any) sensitivity to shock.

From the point of safety in transportation, Pepin Lehalleur (Ref 3, pp 495-97) divides exps, propnts and pyrotechnics into the following four groups, starting with the more dangerous materials:

1) Most dangerous group: Black Powder and colloidal propellants, in bulk placed in boxes; and chlorate explosives, not cartridge,

Dynamites: with attached caps; fuses, detonators, nonelectric & electric and Nitrocelluloses wetted with at least 25% water. Aromatic nitrocompounds, packed in double containers; the inner ones from leather, cardboard, heavy paper envelope, while the outer ones of wood or copper. The fulminates must be transported in vessels filled with water.

The boxes must be transported in special, covered vehicles.

2) Second group, less dangerous to transport than the first one, comprises: pyrotechnic devices, detonating cords w/o caps attached, and Mélinite (PA) cartridges, all placed in barrels of small resistance

3) Third group comprises the "explosifs de sûreté" (to which belong most AN expls) packed in carbon or wooden boxes; then NC wetted with more than 25% water, placed in waterproof containers and finally railroad torpedoes placed in special containers.

4) Fourth group, less dangerous to handle and transport, comprises: shotgun cartridges (for sporting), and military cartridges in finished state and properly packed; fuses without caps attached and igniters for fuses – all these materials must be packed either in wooden or in tinned iron boxes

The materials of the first three groups must be loaded and unloaded in day-time.

The above regulations are those of pre-WWII, but we have no info about current regulations.


FRENCH TESTS FOR EXPLOSIVES AND PROPELLANTS (Arranged in alphabetical order under French names)

Brisance par l'appareil de Calvet. Se Ref 12

Brisance par épreuve de Chalon (Brisance by Chalon Test). See Ref 21, p B299-R & Ref 22, p C493-L

Coefficient de self-excitation (Coefficient of Self-excitation Test), abbr CSE; Aptitude à transmettre la détonation à distance (Capability to Transmit the Detonation at a Distance); Détonation par influence (Detonation by Influence) or Détonation sympatique (Sympathetic Detonation). See Ref 7, p 799; Ref 17, p 74; Ref 19, p 342; Ref 20, p 10 and Ref 23, pp D395-R to D405-L

Coefficient d'utilisation pratique, abbr as CUP or cup (Coefficient of Practical Utilization) or Épreuve de travail spécifique (Specific Work Test). It is Dauttiche's modification of Trautz Lead Block Test. See Ref 20, pp IX & X; Ref 4, p 472; Ref 8, p 171; Ref 10, p 66 & Ref 19, p 344. Also in Ref 24, p E10-R, as Travail spécifique rélatif.
Combustion en gouttière de 20mm (Combustion in a 20mm Trough), also called Épreuve de propagation dans une gouttière de 20mm de diamètre (Propagation Test in a Trough of 20mm Diameter). See Ref 24, p E138-L

Combustion en tas conique (Combustion in a Conical Pile) or Aptitude à l'inflammation, essai (Sensitivity to Inflammation Test in Conical Pile) (See Ref 24, pp E138-R & E139-L)

Courbe de compressibilité des explosifs solides (Curve of Compressibility of Solid Explosives). See Ref 24, p E139-R

CUP or cup. Abbr for Coefficient d'utilisation pratique

Dautriche, Méthode de (pour mesurer la vitesse de détonation) (Dautriche's Method for Measurement of Velocity of Detonation). See Ref 24, p E140-R which includes 8 refs. Detailed description is given in Ref 23, pp C311-R (with Fig) and p C312-L

Densité, Épreuves de (Density Tests). See Ref 17a, p 198; Ref 22, pp D64-R to D81-R

Densité de rassemblement, Essai (Packing Density Test). See Ref 24, p E137-L

Desmaroux, Épreuve de (Desmaroux Test). See Ref 5, p 24; Ref 11, p 90 & Ref 22, p D90-R

Détonation par influence, ou Détonation sympathique, Essai (Detonation by Influence, or Sympathetic Detonation Test). See Transmission de détonation a distance, known in US as Gap Test

Effet utile. See Potentiel

Épreuve au bloc de plomb par compression (Lead Block Test by Compression). See under Épreuve par compression

Épreuve au bloc de plomb, par expansion (Lead Block Expansion Test) or Épreuve de Trauzl (Trauzl Test). Its French modification is known as Coefficient d'utilisation pratique (CUP or cup) or as Travail spécifique rélatif. See Ref 8, pp 171-74 and Ref 24, p E107-R

Épreuve à la bombe (Bomb Test) or Essai de poudre en vas clos (Test of Propellant in Closed Vessel). See Ref 24, p E108-L

Épreuve (ou Essai) au choc des balles (Bullet Impact Test). See Ref 20, p IX; Ref 8, p 215; Ref 15, p 185; Ref 16, p 195; Ref 18, p 283 and Ref 24, p E108-L

Épreuve au choc de mouton (Shock Test by a Ram). The test with a light weight (such as 2kg) is known as “essai au petit mouton”, while test with a heavy weight (such as 30kg) is known as “essai au gros mouton”. These tests are listed under Impact (or Shock) Sensitivity Tests in Ref 20, p XVII. See also Ref 24, p E110-L & Ref 9, p 560

Épreuve de combustion (Combustion Test) or Épreuve de l'aptitude à l'inflammation (Capability to Inflame). See Ref 20, p X & Ref 19, pp 329-30

Épreuve par compression (Compression (or Crusher) Tests), used for testing brittleness, include: Épreuve des petits plombs (Test by Small Leads), Ref 22, p C492-R; Essai par l'appareil de Chalon (Test by Apparatus of Chalon), Ref 22, p C493-L; and Essai par appareil de Quinan (Test by apparatus of Quinan), Ref 22, p C493-R

Épreuve à la dynamite de pilotis (Test of a Dynamite by Piles). See Ref 24, p E108-R

Épreuve de la finesse des coton-poudres (Fineness Test for Nitrocelluloses). See Ref 24, p E108-R

Épreuve des petits plombs (Small Lead Blocks Test). See Ref 24, p E109-L & R
Épreuve de la résistance à la chaleur (Resistance Test). See Ref 20, p XXI & Ref 24, p E110-L. Also described in the Book of Instruction, issued about 1950 by the Commission des Substances Explosives (CSE), Chapitre III, Articles 95–107 and Chapitre IV, Articles 230–31. The book can be obtd from the 2ème Bureau de l’Armée, Paris, France

Épreuve de la résistance à l’exsudation (Resistance to Exudation Test). See Ref 24, p E110-L

Épreuve de sécurité (Security or Safety Test). See Ref 24, p E110-L

Épreuve de la sensibilité à l’amorce (Sensitivity to Primer Test). See Ref 24, p E110-R

Épreuve de la sensibilité à l’inflammation (Sensitivity to Ignition Test). See Ref 24, p E110-R

Épreuves de stabilité des explosifs et des poudres (Stability Tests for Explosives and Propellants). See Ref 24, p E110-R

Épreuve de Taliani (Taliani Test). See Ref 6a, p 837; Ref 11, p 88 and Ref 20, pp XXIV & XXV

Épreuve de tir au mortier ou Essai au mortier éprouvette (Firing Test from Mortar). See Ref 8, p 189; Ref 10, pp 66–7 & Ref 20, p XIX

Épreuve de Trauzl (Trauzl Test). See under Épreuve au bloc de plomb par expansion

Érosion (ou usure) des bouches à feu (Erosion of Gun Barrels). See Ref 24, pp E112-R to E120-R; Ref 8, pp 274–78; Ref 10, p 102 & Ref 13, pp 115–16

Essai avec l’appareil de Quinan (Test With Apparatus of Quinan or Quinan Test). See Ref 8, p 192; Ref 10, p 63 & Ref 22, pp C493-R & C494-L

Essai dans le béton (Concrete Test). It is modification of Essai de Trauzl. See Ref 3, p 105; Ref 4, p 473 & Ref 22, p C495-R

Essai au choc des balles. See Épreuve au choc des balles

Essai de Dautriche pour mesurer la vitesse de détonation (Dautriche’s Method for Measurement of Detonation Velocity). See Dautriche, Méthode de

Essai de déflagration (Deflagration or Ignition Test). See Ref 8, p 211; Ref 10, pp 110–11; Ref 11, pp 66 & 83 and Ref 24, pp E135-R & E136-L

ESSAIS d’EXPLOSIFS. Fourteen French official tests devised at the Laboratoire de la Commission des Substances Explosives (CSE) and described in Ref 19, are also described in Ref 24, pp E137-L to E140-R

Essai à la friction (Friction Sensitivity Test). See Ref 8, p 212; Ref 10, pp 75–6; Ref 20, pp XIII–XIV and Ref 24, p E136-L

Essai au mortier éprouvette (Ballistic Mortar Test). See Ref 20, p VII; Ref 8, p 189 & Ref 24, p E136-L & R

Essai au pendule balistique (Ballistic Pendulum Test). See Ref 20, pp VII & VIII; Ref 8, p 269 and Ref 24, p E137-L with Fig E131

Essai au sable (Sand Test). See Ref 20, pp XXI & XXII

Essai dans la terre (Earth Test), known in US as Cratering Test. See Ref 3, p 101; Ref 10, p 67; Ref 13, pp 80–1 and Ref 22, p C554-R, under Cratering Effect Tests

Exsudation, Essais (Exudation Tests). See Ref 4, p 419; Ref 10, p 61; Ref 11, p 65; Ref 19, p 323 and Ref 20, p XI
Exsudation par étuvage, Essai (Exudation on Storing Test). See Ref 24, p E138-L

Galleries d’essais (Galleries for Testing). See Ref 8, pp 235–42; Ref 20, p XIV & Ref 22, p C371-L & R

Marqueyrol, Épreuve de (Marqueyrol Test). See Ref 6, p 178 & Ref 11, p 90

Mesures calorimétriques (Calorimetric Tests). See Ref 20, p IX & Ref 8, pp 60–7

Potentiel ou Effet utile, Essai (Potential or Useful Effect Test). See Ref 10, pp 43 & 64; Ref 13, p 76 & Ref 20, p XX (See also under Pouvoir)

Pouvoir ou Force des explosifs, Essais (Power or Strength of Explosives, Tests). See Ref 20, p XX and as Étude de l’effet utile or Rendement pratique en travail d’un explosif in Ref 8, pp 166–89 & 192–93. The test is also known as Coefficient d’utilisation pratique, Essai

Pressions développées en combustion des poudres, Essai (Pression Developed on Combustion of Propellants). See Ref 8, pp 50–1; Ref 13, pp 73–4 & Ref 20, p XX

Produit caractéristique de Berthelot (Characteristic Product of Berthelot). See Ref 21, p B105; Ref 8, p 53 & Ref 13, p 70

Reprise d’humidité, Essais de (Hygroscopicity Tests). See Ref 19, p 325; Ref 20, p XVI and Ref 24, pp E137-R & E138-L

Sensibilité à l’amorce, Essai (Sensitivity to Priming Test) or Initiating Efficiency of Primers or Detonators. See Ref 10, pp 68–9; Ref 20, p XVIII and Ref 24, p E140-L

Sensibilité au choc du petit mouton (de 30kg) (Sensitivity to Shock With a Big Ram of 30kg which means Impact Sensitivity With 30kg Weight). See Ref 24, p E139-L

Sensibilité au choc du petit mouton (Sensitivity to Shock with Small Ram, which means Impact Sensitivity With Small Weight). See Ref 24, p E139-L

Sensibilité au choc de mouton, Essais (Sensitivity to Shock of a Ram, Tests). Same as Amer Impact (or Shock) Sensitivity Tests. See Ref 8, pp 213–15; Ref 9, pp 560–61; Ref 13, pp 81–3 and Ref 20, p XVII. See also Sensibilité au choc du gros mouton and au choc du petit mouton

Transmission de détonation à distance (Transmission of Detonation at a Distance), known as Aptitude à transmettre la détonation à distance (Ability to Transmit the Detonation at a Distance). See Ref 24, E140-L. Same as Detonation by Influence, Sympathetic Detonation or Gap Test

Transmission de la pression dans un explosif pulvénlement (Transmission of Pressure in a Powdered Explosive). See Ref 24, p E139-R

Sensibilité à l’amorce (Sensitivity to Primer). See Ref 24, p E140-L

Travail spécifique relatif (Specific Relative Work) or Coefficient d’utilisation pratique (CUP or cup) (Coefficient of Practical Utilization); corresponds to Trauzl Block Test modified in 1912 by the French Commission des Substances Explosives (CSE). See Ref 24, p E140-L

Vieille, Épreuve de (Vieille Test). See Ref 4, p 661 & Ref 11, p 78

Vitesse de détonation mesurée par la méthode de Dautriche (Detonation Velocity Measured by the Dautriche’s Method). See Dautriche, Méthode de (pour mesurer la vitesse de détonation), in this section

Vivacité de combustion des poudres (Quickness of Burning of Propellants). See Ref 13,

French Verge Gelatin. See Vol 5 of Encycl, p D1291, Table 1

French Weapons of WWII. We are listing them (See Table F19 taken from Ref 1) because it is presumed that some of them are still used. No nation (except the US) can afford to change models every few years. Calibers of Fr weapons are in millimeters and abbr Mle is for Modèle (Model)

Table F19

<table>
<thead>
<tr>
<th>German Name</th>
<th>Original Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5-cm Pak 34 (f)</td>
<td>25 Mle 1934</td>
</tr>
<tr>
<td>2.5-cm Pak 113 (f)</td>
<td>25 Mle 1937</td>
</tr>
<tr>
<td>3.7-cm Kw.K.143 (f)</td>
<td>37 SA de char Mle 1938</td>
</tr>
<tr>
<td>3.7-cm Kw.K.144 (f)</td>
<td>37 SA de char Mle 1918</td>
</tr>
<tr>
<td>4.7-cm Kw.K.173 (f)</td>
<td>47 de char Mle 1935</td>
</tr>
<tr>
<td>4.7-cm Pak 181 (f)</td>
<td>47 Mle 1937</td>
</tr>
<tr>
<td>4.7-cm Pak 183 (f)</td>
<td>47 Mle 1939</td>
</tr>
<tr>
<td>7.5-cm K.231 (f)</td>
<td>75 Mle 1897</td>
</tr>
<tr>
<td>7.5-cm K.232 (f)</td>
<td>75 Mle 1897/33</td>
</tr>
<tr>
<td>7.5-cm Geb.K.238 (f)</td>
<td>75 Mle 1928</td>
</tr>
<tr>
<td>7.5-cm Kw.K.251 (f)</td>
<td>75 Mle 1897</td>
</tr>
<tr>
<td>10.5-cm K.331 (f)</td>
<td>105 L Mle 1913</td>
</tr>
<tr>
<td>10.5-cm K.332 (f)</td>
<td>105 L Mle 1936S</td>
</tr>
<tr>
<td>10.5-cm L.F.H.324 (f)</td>
<td>105 C 1934S</td>
</tr>
<tr>
<td>10.5-cm L.F.H.325 (f)</td>
<td>105 C 1935B</td>
</tr>
<tr>
<td>14.5-cm K.405 (f)</td>
<td>145 Mle 1916</td>
</tr>
<tr>
<td>15.5-cm s.F.H.414 (f)</td>
<td>155 C Mle 1917</td>
</tr>
<tr>
<td>15.5-cm s.F.H.415 (f)</td>
<td>155 C Mle 1915C</td>
</tr>
<tr>
<td>15.5-cm K.416 (f)</td>
<td>155 L Mle 1917</td>
</tr>
<tr>
<td>15.5-cm K.417 (f)</td>
<td>fra G.P.F., CA</td>
</tr>
<tr>
<td>15.5-cm K.418 (f)</td>
<td>155 G.P.F.</td>
</tr>
<tr>
<td>15.5-cm K.419 (f)</td>
<td>155 G.P.F.T.</td>
</tr>
<tr>
<td>15.5-cm K.420 (f)</td>
<td>155 Mle 1916</td>
</tr>
<tr>
<td>15.5-cm K.422 (f)</td>
<td>155 L Mle 1877/1914</td>
</tr>
<tr>
<td>15.5-cm K.425 (f)</td>
<td>155 L Mle 1918</td>
</tr>
<tr>
<td>15.5-cm K. G.P.F. (f) Ortfeux</td>
<td>164 Mle</td>
</tr>
<tr>
<td>16.4-cm K. (E) 453 (f)</td>
<td>164 Mle 93/96</td>
</tr>
<tr>
<td>16.4-cm K. (E) 454 (f)</td>
<td>194 Mle 70/93</td>
</tr>
<tr>
<td>19.4-cm K.70/93 (E) (f)</td>
<td>194 G.P.F.</td>
</tr>
<tr>
<td>19.4-cm K. G.P.F. (f)</td>
<td>194 G.P.F. sur chenilles</td>
</tr>
<tr>
<td>19.4-cm K.485 (f) (SR)</td>
<td>220 C Mle 1916</td>
</tr>
<tr>
<td>22-cm Morter 351 (f)</td>
<td>220 L Mle 1917</td>
</tr>
<tr>
<td>22-cm K.532 (f)</td>
<td>240 Mle 93/96 M</td>
</tr>
<tr>
<td>27.4-cm K. (E) 537 (f)</td>
<td>274 Mle 17</td>
</tr>
<tr>
<td>27.4-cm K. (E) 592 (f)</td>
<td>Mortier 280 14/16</td>
</tr>
<tr>
<td>28-cm Mle 601 (f)</td>
<td>Mortier 280 sur chenilles</td>
</tr>
<tr>
<td>28-cm Mle 602 (f)</td>
<td>320 Mle 70/84 or 70/93</td>
</tr>
<tr>
<td>32-cm K. (E) 657 (f)</td>
<td>340 Mle 12 (A Glissement)</td>
</tr>
<tr>
<td>34-cm K. Gl.(E) 673 (f)</td>
<td>340 Mle 12 (S Berceau)</td>
</tr>
<tr>
<td>34-cm K. W.(E) 674 (f)</td>
<td>370 Mle 1915</td>
</tr>
<tr>
<td>37-cm H. (E) 711 (f)</td>
<td>370 Mle 75/79</td>
</tr>
<tr>
<td>37-cm K. (E) 714 (f)</td>
<td>400 Mle 1915/16</td>
</tr>
<tr>
<td>40-cm H. (E) 752 (f)</td>
<td>520 Mle 18</td>
</tr>
</tbody>
</table>
The following French WWII mines and
traps (mines et mine-pièges) are listed in
Ref 3, pp 206–09:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Overall Height</th>
<th>Overall Length</th>
<th>Overall Width</th>
<th>Type of Filling</th>
<th>Wt of Filling</th>
<th>Total Wt</th>
<th>Igniter</th>
</tr>
</thead>
<tbody>
<tr>
<td>60mm Model 1939 Antipersonnel Mine</td>
<td>8.25”</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Mélinite</td>
<td>5 oz</td>
<td>5.5 lb</td>
<td>Unknown</td>
</tr>
<tr>
<td>Light Antitank Mine</td>
<td>4.4</td>
<td>12–11”</td>
<td>8.11”</td>
<td>Same</td>
<td>Unknown</td>
<td>13.4</td>
<td>Pressure type</td>
</tr>
<tr>
<td>Heavy Antitank Mine</td>
<td>4.75</td>
<td>16.2</td>
<td>9.85</td>
<td>Same</td>
<td>3.25 lb</td>
<td>27</td>
<td>Pressure type</td>
</tr>
</tbody>
</table>

For initiating the mines and traps, the following devices are listed in Ref 3, pp 211–213, under the title "French Igniters":
1) Rupture Igniter (p 211)
2) Pull Igniter Model 1939 (p 211)
3) Push and Pull Igniters (p 212–13)

We have no information about weapons used
after WWII by the French, but presume that
they are still using some of the WWII items
Refs: 1) Anon, FAJ (Field Artillery Journal)
34, 641 (1944) 2) G.B. Jarrett, FAJ 35, 669
(1945) 3) Anon, "Italian and French Explosive
Ordnance", OP (Ordnance Pamphlet)
1668 (1946), pp 206–09

Frequency Tailored Transducers. These ICP
(Integrated-Circuit-Piezoelectric) transducers,
intended for shock wave, blast, and other expl
measurements, are claimed to produce micro-
second rise time with high damping to produce
clean readable results in instantaneous press-
ure measurements. Available in ranges to
100000psi, they feature acceleration compen-
sation, 500000Hz frequency response and a
built-in IC amplifier to provide a high voltage
low output impedance signal. Low Impedance
outputs can be operated thru standard coaxial
cable without noise or attenuation problems.
Frequency tailoring is said to be accom-
plished by extensive shock wave testing during
production and final test to assure good dyna-
ic response from each transducer produced.
It also avoids rectification errors (no-symmetri-
cal clipping) in signal conditioning electronics.

The output signal approaches that of a non-
resonant transducer while retaining the versa-
tility and capability of measuring long duration
events
Refs: 1) Technical Bulletin No 11370, PCB
Piezotronics, Inc, PO Box 33, Buffalo, NY
14225 2) Explos&Pyrots 3(5)(1970)

Fresenius, Karl Remigus (1818–1897). A
German chemist noted for his work on analyti-
cal chemistry. Designed a desiccator with
bell-shaped cover and a nitrogen bulb in the
shape of a conical flask with side-tubes
having two bulbs near the base
Ref: Hackh’s Dict (1944), p 357-R

Fresnel, Augustin Jean (1788–1827). A French
physicist noted for his work on optics, such as
aberration of light, interference, wave theory
of light, etc. He constructed the first prac-
tical "interferometer", which is used at pre-
sent in modified form in Ordnance, such as
"interferometric analysis of air flow about
projectiles in free flight"
Refs: 1) Encyclopedia Britannica, Vol 9
(1929), p 836 2) Hackh’s Dict (1944), p
357-R
Frettage. A French term for the process of constructing a “built-up gun” by means of driving on its barrel heated steel circular bands or rings (hoops). These hoops shrank on cooling and thus hold the walls of barrel tight. Other methods to construct built-up guns are described in Ref 2

Friction and Lubrication (Frottement et Lubrication, in French). Friction is the act of rubbing the surface of one body against that of another. It may also be called resistance to relative motion between two bodies in contact. In the case of two solids in contact, with the surface of one sliding over that of the other, the name friction is applied to the force which resists the relative motion of the two bodies. A number (f) indicating the relation of the force (F) just to move an object along a horizontal plane under a pressure (N) is called friction coefficient: \( f = F/N \)

Sliding friction is caused by inequalities in the surfaces and depends on the materials of the substance, but not on the velocity or area of the surfaces in contact

In the case of liquids each particle rubs against the other and this is called internal fluid friction or viscosity

In order to eliminate or diminish the friction, so-called lubricants are used. These substances (such as oils, fats, greases or finely pulverized materials like tallow) possess the property to make the surfaces slippery when interposed between moving parts. Lubrication is the act of making the rubbing surfaces slippery by applying a lubricant

Frictional Impact Test. See under friction SENSITIVITY TESTS in Vol 1, p XIII

Friction Composition for Blasting Fuse. See Vol 4, p D1071-L

Friction Compositions for Friction Detonators; Friction Firing Devices and Friction Igniters or Primers. These are powders which are easily ignited by friction. Some of the simplest mixtures are K chlorate with sugar or with antimony sulfide. Davis (Ref 1, p 453) gives table listing three compns which have been widely used in friction primers for artillery, separate-loaded ammunition

<table>
<thead>
<tr>
<th>Component</th>
<th>No 1</th>
<th>No 2</th>
<th>No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chlorate</td>
<td>66.67</td>
<td>56.2</td>
<td>44.6</td>
</tr>
<tr>
<td>Antimony sulfide</td>
<td>33.33</td>
<td>24.6</td>
<td>44.6</td>
</tr>
<tr>
<td>Sulfur</td>
<td>-</td>
<td>9.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Meal powder</td>
<td>-</td>
<td>-</td>
<td>3.6</td>
</tr>
<tr>
<td>Ground glass</td>
<td>-</td>
<td>10.2</td>
<td>3.6</td>
</tr>
</tbody>
</table>

All the materials are in a powdered condition except the No 1 mixture, where half of the K chlorate is powdered and half of it is granular. The sulfur, which is coars in No 2 and No 3 mixts, makes them more sensitive, but also may make them turn sour after wet-mixing of the components. In order to prevent this, small amts of antacids (such as Ca
carbonate or trimethylamine) should be incorporated. All three mixs are wet-mixed with 5% gum-arabic soln, loaded wet, and dried out in situ to form pellets (Ref 1, pp 453–54).

Two of these mixs (No 2 & No 3) are listed in Ref 2, p D758-R as “match mixtures”.

Many of the compositions suitable for use in Percussion Primers (such as listed in Ref 3, pp D792-R to D805-R) may be ignited not only by percussion but also by friction. See also Instantaneous Percussion Fuze Primers, pp D852-L to D854-L.


**Friction Detonators.** The following types of devices intended for initiating demolition charges, land mines and some underwater charges are described in Vol 4 of Encycl: Friction Detonator, 8-Second Delay, M2 (p D804-R & Fig 67) and Friction Detonator, 15-Second Delay, M1 (p D805-R & Fig 66).

French Friction Detonators are in Ref Re/ Société Alsasiennne d’Explosifs, FrP 102355 & CA 52, 3346(1958).

**Friction Element, Moisture Resistant.** A moisture resistant friction element is prep from a coating compn comprising 100 parts of amorphous P, Sb, and ground glass in 75 parts of plasticized polystyrene emulsion


**Friction Firing Devices.** One Pull-Friction Type Firing Device, M2, is described in Vol 4, pp D770-R & D771-L & R with Fig 26. It has been used for firing booby traps.

**Friction; Heat and Percussion in Relation to.** Expts on friction and percussion sensitivity,

and on sensitization by heat vs sensitization by mechanical shock indicate that a greater volume of Hg Fulminate than of Pb Azide is reqd for build-up of deton. The hot spots due to grit generate the deton wave more easily in Azide than in Fulminate. Percussion sensitivity is apparently more complex involving, in addn to the formation of hot spots thru friction, a frig-chemical reaction in which there is a direct transfer of mechanical to activation energy than is the case when the mechanical energy is converted into heat


**Friction Igniters or Primers** (Also known as Friction Tubes). They are devices for the production of fire by the friction of the thrust, either push or pull, of a roughened rod or wire thru a pellet of a special primer composition, such as listed here under Friction Compositions. They are used for firing propelling charges in separate-loaded artillery ammunition. One of such friction primers, M1914, is briefly described in Ref 2, p D795-L.

They are sometimes crimped to an end of Buckford fuse for the purpose of lighting it (Ref 1, p 453). Such a device known as Time Blasting Fuse Igniter M1 is described in Ref 2, p D766-R with Fig 19 and on p D762-L.

They also are sometimes used for lighting flares, which are thrown overboard from airplanes. For this use, the pull element of the primer is attached to the airplane by a length of twine or wire which is pulled and broken off by the weight of falling flare (See Fig 2-25 in Ref 2, p D957). In one type of the primers for airplane flares, ignition is achieved by pulling a loop of braided wire coated with red phosphorus and shellac thru a pellet made from K chlorate (14 parts) and charcoal (1.6 ps), hardened with dextrin (0.3 p)(Ref 1, pp 453–54). This type of igniter is also listed in Ref 2, p D758-R & D759-L.

Compositions used in friction primers are listed under Friction Compositions (Compare with Friction Detonators and Friction Firing Devices)
Friction Sensitivity. The importance of standardizing the method and instrument for determining and comparing the sensitivity to friction of expl materials is discussed by Bowden et al. (Ref 1) and Kinoshita and Arimura (Ref 2). Bowden points out that, using NG as an example, no expln occurs until a certain minimal temp is attained from the conversion of mechanical to thermal energy.

Friction Sensitivity Tests (Quantitative). The following tests are briefly described in Vol 1 of Encycl, pp XIII & XIV:

a) Ratiburg Test, using two steel discs, one stationary, another rotating over it. Similar apparatus is described in Ref 1, p 25, Fig 9
b) US Bureau of Mines Pendulum Friction Apparatus
c) Taylor & Rinkenbach's Small Model of Bureau of Mines Pendulum Apparatus
d) Impact Friction Pendulum of Spencer Chemical Co

To these may be added:
e) Friction Pendulum Test using apparatus shown in Fig 8 on p 24 of Ref 1, reproduced here as Fig F19. A small, weighed, charge of expl is placed in a depression made in an anvil, which can be of steel, bronze, hardwood or of other materials. A steel shoe 2, varying in wt from 1 to 20kg, can be attached to the end of pendulum 3. Then 3 is raised to a predetermined height (indicated on scale 4) and released to swing. If no expln is produced during swinging, a new sample is placed on the anvil and a heavier shoe is used. The test is repeated with heavier shoes until explns are produced. The same results sometimes can be produced by just raising the height of fall of pendulum.

f) Friction Test Using Apparatus of Bowden, shown in Fig 7 of Ref 2, reproduced here as Fig F20. Here, a thin layer of expl, compressed with predetermined pressure, by
means of screw 1, between a steel roll 2 and sliding plate 4 is subjected to friction when pendulum 5 hits the plate from a predetermined height. If no expln takes place, the test is repeated with pendulum falling from greater height, etc.

**g) Friction Test for Liquid Explosives**, using app shown in Fig 6.6-a on p 73 of Ref 3. Here the expl is smeared on the surface of a rotating disc on which rests a rod of similar or dissimilar material, carrying a known wt. The speed of rotation can be varied and also the load employed. The higher the speed and the greater the load before initiation of expl, the lower is the sensitivity of expl. Sometimes an oscillating plate is used instead of a rotating disc.

**h) Friction Test for Solid Explosives**, using an app shown in Fig 6.6-b on p 73 of Ref 3, reproduced here as Fig F21. Here, a rotating wheel with rough surface rubs against the sample. The speed of wheel or its pressure against expl can be varied.

**i) Torpedo Friction Test**, using an app shown in Fig 6.8 on p 75 of Ref 3, reproduced here as Fig F22. It determines the effect of a blow which is to some extent at a glancing angle.
This is a common hazard in the handling of expls. In this test, a torpedo weighing 0.5 to 5 kg slides down an inclined plane at an angle 70 or 80° to strike the expl resting on an anvil. The head of the torpedo and the material of the anvil can be varied, as well as the height of fall. Some results of tests are shown in Table 6.1 on p 76.

j) Friction Test Using Apparatus of Bowden-Kozlov, shown in Fig 10 on p 43 of Ref 4, reproduced here as Fig F23. Here, a small charge of expl 4 is compressed between rolls 1 & 3 by means of piston 5 actuated by hydraulic press (not shown) and sliding thru cylinder 6. The upper roll 1 slides between support 2 and expl 4 when it is hit by rod with head 7, on being struck by a pendulum (not shown) from a predetermined height. The pressure on piston 5 is varied until 50% of expls are obd.

Refs: 1) Yaremko & Svetlov (1957), 24–5
2) Gorst (1957), 32–3 (Not in Ref 4)
3) Fordham (1966), 73–5
4) Gorst (1972), 43–4 (Not in Ref 2)
(See also Refs 1 to 15 on p XIV of Vol 1 of Encycl)

Friedel-Crafts Reaction. Any organic reaction brought about by the catalytic action of anhydrous aluminum chloride or related, so-called Lewis acid type catalysts. Discovered in 1877 by C. Friedel and J.M. Crafts, who later uncovered most of the types of reaction such as substitution, isomerization, elimination, cracking, olefin polymerization, addition, etc. Commonly used to displace an aromatic hydrogen atom with an alkyl, aryl or acyl chain

2) Kirk & Othmer 10, pp 135–166 (1966)

Friedler's Incendiary Composition consisted of a mixture of crude rubber and metallic sodium or potassium, which was intended to burn while floating on the surface of water.

Ref: Daniel (1902), 310

Fringing Groove. During firing, a small amount of copper of the rotating band is forced back behind the band and along the surface of the projectile in the rear of the band. The pressure of the released gas at the muzzle of the weapon and the centrifugal force of rotation combine to throw this excess metal out in a radial direction so that it becomes a fringe around the rear part of the band. When this fringe is excessive and irregular, it builds up air resistance, lessens stability in flight and causes decreased range and decreased accuracy. This excessive fringing can be eliminated if, on machining the band, a groove is cut all around and in the rear of it.

Ref: Glossary of Ordn (1959), 124-L

Frittage (Fr). Sintering (Powder Metallurgy)

Front of Detonation Measurements
A photoelectric technique has been devised whereby the position of the deton front in an expl can be measured. The light from the deton front is transmitted by a small-diameter optical fiber to the cathode of a photomultiplier tube where the light pulse is converted to an electrical pulse. Additional pulses may be generated by other fibers located elsewhere in the expl. All of the pulses may be recorded on an oscilloscope. The usefulness of the technique has been demonstrated by the measurement of the transmission times of detonators, the propagation velocities of expl columns, the timing of expl systems, the velo
of shock fronts in air, the arrival of shock fronts thru inert materials, and the position of the deton from inside an expl

Front of Detonation, Non-Planar. See Vol 4, pp D349-R & D350-L

Front of Detonation and Shock Front, also Detonation Zone and Shock Zone. See Vol 4, pp D350 & D351-L

Front of Reaction in Detonation. See Vol 4, p D503

Frozen Blasting Gelatin. Blasting Gelatin (See Vol 2, p B211-R) exists as a yellowish translucent, elastic mass of density about 1.63. It is very difficult to freeze. When frozen, it loses its elasticity and flexibility, and becomes a hard white mass. Unlike Guhr Dynamite and Straight Dynamite, it is more sensitive to shock when frozen than when in a soft and unfrozen state
Refs: 1) Naoum, NG (1928), 311–12 2) Davis (1943), 343

Frozen Dynamite. All straight Nitroglycerin expls can be frozen. Straight Dynamite when frozen becomes less sensitive to shock and to initiation, but Blasting Gelatin becomes slightly more sensitive. When the expls are afterwards thawed, the NG shows a tendency to exude. Frozen Guhr Dynamite is less sensitive (a drop of more than 1 meter of a kilogram weight or of at least 20cm of a 2kg wt is necessary to explode it). Frozen or unfrozen it can be exploded in a paper cartridge by the impact of a bullet from a military rifle
Refs: 1) Naoum, NG(1928) 2) Davis (1943) 210, 334, 336

Frozen Gravel Blasting. Underground blasting in permanently frozen gravel was studied in a 7~ by 12-foot tunnel by running a nonreplicated 2x2x? factorial experiment on the effects of type of cut, delay and expl on the fragmentation sub-system. Comparisons were made between a V-cut round and burn-cut round, millisecond delays and half-second delays, using 40% Special Gelatin and 60% High-Density Ammonia Dynamite. None of the differences between delays and expls was notably significant. Results of tests are presented in Refs 1 & 3 and abstracts are given in Refs 2 & 4

Frozen Nitroglycerol. NG crystallizes in two forms: a stable form, dipyramidal rhombic crystals which melt or freeze at 13.2–13.5°, and a labile form, glassy-appearing triclinic crystals, mp 1.9–2.2°. It does not freeze readily or quickly. NG in Dynamite freezes in crystals if the expl is stored for a considerable length of time at low temps, its form depending upon the materials with which it is mixed. By virtue of the fact that frozen NG could not be detonated, transportation in the early days of its use was made safer by shipping it in the frozen state
Refs: 1) Naoum, NG(1928), 110–111 (Freezing and melting of NG) 2) Davis (1943), 207, 212

Fructosans are a group of sugar anhydrides which hydrolyze to fructose. One of its derivatives, Fructosan Trinitrate, is prep'd from fructose
Ref: Hackh's Dict (1944), 358-R
Fructosan Trinitrates. Its alpha form, \( \alpha-C_6H_7O_4(ONO_2)_3 \), mw 297.14, N 14.14%, OB –24.2%; is produced by the action of mixed acid at 0–15\(^\circ\) on d-fructose or on laevulosan; colorless, quickly efflorescing needles from alcohol, which melt at 139–140\(^\circ\) and decompose at about 145\(^\circ\). It is readily sol in methyl and ethyl alcohols, acetic acid, and acetone; insol in w. Relatively stable at 50\(^\circ\). It reduces hot Fehling’s solution.

The alcoholic mother liquors from the \( \alpha \)-form yield fructosan trinitrate \( \beta \), crusts of white crystals which melt at 48–52\(^\circ\) and decompose at 135\(^\circ\). The material decomposes slowly at 50\(^\circ\). It reduces Fehling’s soln rapidly on warming.

Refs: 1) Beil 1, 925 2) Marshall 1(1917), 197 (Lists the compds as Levulose Trinitrate, \( \alpha \) & \( \beta \) and states that they are stable expls) 3) A. Piccet & J. Reilly, HelvChimActa 4, 613(1921) 4) Davis (1943), 243

Fructose or Laevulose (Levulose, Fruit Sugar, D(-)-Fructose or Hexose), C\(_6\)H\(_{12}\)O\(_6\); mw 180.16; yellowish white crysts, sp gr 1.669 at 17.5\(^\circ\), mp 103–05\(^\circ\)(dec), sol in w, alc & acet. A sugar occurring naturally in fruits and honey; it is the sweetest of the common sugars. Can be prepd by the hydrolysis of inulin or of beet sugar, followed by lime separation. Used in foodstuffs, medicine and as preservative. Can be nitrated by dissolving it in nitric acid, adding sulfuric acid, separating, washing with ice water and purifying by recryst from alc (See Frucrosean Trinitrate, called Levulose Trinitrate by Marshall


FS. Abbreviation for Fuse

FS. Abbr for Fin Stabilized

FS. Chémical agent consisting of a mixture of \( \text{SO}_3 \) and chlorosulfonic acid used for producing smoke. It has been produced by the US Chemical Corps.

Chlorosulfonic acid can be made by reaction of \( \text{SO}_3 \) and HCl

Ref: A.M. Ball, Ordnance 37, 430(1952)

Fuchs or Clement Powder. See Clement or Fuchs Powder in Vol 3 of Encycl, p C329-L

Fuel. Any material which produces heat on combustion is known as fuel. Fuels may be divided into solid (coal, lignin, coke, wood, sawmill waste, bagasse, bark, straw, and peanut, cottonseed & sunflower seed shells); liquid (fuel oils, crude petroleum, kerosene, gasoline, Diesel oil, mazut, coal tar oil, alcohol, benzene and synthetic liquid fuels); gaseous (acetylene, blast furnace gas, blue water gas, hydrogen, methane natural gas, oil gas, petroleum gases, producer gas, reformed gas, and commercial butane & propane gases)

Among the solid fuels, only coal & coke are of any importance in the US (See Vol 3 of Encycl, p C352-L for "Coal" and p C391-R for "Coke"); among liquid fuels are petroleum products, especially fuel oils (qv); and among gaseous fuels are natural gases

Besides using coal as a straight fuel, it is used in pulverized state as an ingredient of many commercial expls. They are described in Vol 3 of Encycl, under "Coal Dust and Its Uses", pp C358-L to C359-R. Coal dust was also proposed to be used in "Coal Dust Bomb", briefly described on p C359-R. Coal hydrogenation and coal liquefaction are described under "Coal Processing for Obtaining More Valuable Products", listed on p C379 and in Refs 3, 7 & 11 listed on p C380-R. Among the fuels obtd from coal, may be listed: coal oil (p C379-L), coal tar (p C379-R). Another solid fuel, coke, which is obtd as residue after removing volatile products from bituminous coals (See pp C391-R & C392-L), is used
not only as a straight fuel, but also as a component of commercial expls, as, for example, Dahmenites and Golovine Explosive, listed on p C392-L. Other solid materials used either straight as fuels or as ingredients of explosives are sawdust, charcoal, cereal flours, cellulose, etc.

Liquid fuels, such as crude petroleum, mazut, fuel oils, etc are used not only as straight fuels, but also as ingredients of expls, such as AN—FO. They are also used for coarsing hygroscopic crystals or grains (such as Amm or Na nitrates) used as ingredients of expls. Such coarings also serve as sensitizers for oxidizing salts.

Light liquid fuels, such as gasoline, are used in frangible incendiary bombs, in flame throwers, as driving energy of aeroplane and automobile motors, while heavier combustible liquids are used for driving Diesel engines. Methyl- and ethyl alcohols can be added to gasoline in case of its shortage.

Beginning before and during WWII many liquid fuels started to be used for propulsion of jet and rocket motors and for spacecraft.

Gaseous fuels are used not only as straight fuels, but also for driving engines similar to automobile motors. Due to shortage of gasoline, many automobile engines were converted during WWII in Germany and France to use coal gas.

Sometimes electrical energy when used as a source of heat can be classified as a fuel.


Fuel-Air Explosives. See FAX

Fuel Cells. Accond to Young & Roselle (Ref 1), the fundamental principles of operation of a fuel cell are essentially the same as that of all galvanic cells. There are two basic half-cell reactions – one involving oxidation and releasing electrons, the other involving reduction and requiring electrons. The two half-cells are separated by an electrolyte barrier so that reaction can occur only by migration of ions. An arrangement of two half-cells is shown in Fig 1 where the fuel is oxidized i is hydrogen and the material reduced is the oxygen of the air. The electrolyte is an aqueous soln of Na hydroxide and the hydroxyl ions serve to transport the oxidizing agent to the fuel electrode. Fuel cells, operating at ambient temps and employing fuel gases are capable of a fuel oil efficiency of 70 to
80%, compared with an efficiency of about
35% for a steam plant operating on coal. Other
advantages of fuel cells are their high ratio of
electrical energy per unit weight, adaptability to both large and small scale applications,
and long running life and storage characteristics. Different types of cells are
carbon cells, gas cells and Redox cells. Car-
bon cells are those in which carbon is used
directly as the fuel electrode. For example,
in such a cell coal is used as the anode
where it is oxidized to carbon dioxide in the
half-cell reaction. These cells are inefficient,
require high temp (800–1000°C) operation to
increase the reaction rate, and at these temps,
much of the fuel electrode is converted to
carbon dioxide. In a gas cell, fuel gases
such as hydrogen or carbon monoxide are used
as a fuel. Oxidation of the fuel gases by the
electrolyte can be achieved at moderate temps
by the use of proper catalysts, and in most
cases no side-reactions occur. A Redox cell
makes indirect use of the fuel as a reducing
agent. Electrolyte solns, which are separated
by a membrane impermeable to the active ions,
contain ions that undergo oxidation and reduc-
tion in the cell. The electrolyte solns are
regenerated by using carbonaceous fuel for
reduction and air for oxidation. The only one
considered for commercial development is the
fuel gas cell. Table 1 is a summary of
several fuel gas sources and applicability
in various power sources.

Accdg to CondChemDict(1961)(Ref 2) and
1971 edition (Ref 3) the term fuel cell can
mean rubberized tanks for the storage of li-
quid fuels and also the following:

Electrochemical devices for the continu-
ous production of electricity by conversion of
chemical energy of a continually supplied fuel
and oxidant. Like primary cells and storage
batteries, fuel cells supply low voltage, di-
rect current energy, but unlike these fuel cells
are converters rather than storage devices and
produce energy as long as they are supplied
with fuel and oxidant. Fuel cells have ad-
vantages over storage batteries w/o the ne-
nenessity for recharging.

The principal types of fuel cells under
development are:

a) Hydrox, utilizing hydrogen fuel and air or
oxygen, the reaction product, water, must be
continuously removed from the cell, usually by
evaporation or condensation. One form uses
aq KOH electrolyte, while another employs

<table>
<thead>
<tr>
<th>Fuel Gas</th>
<th>Source of fuel gas</th>
<th>Cell applications</th>
<th>Remarks</th>
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<tr>
<td>Hydrogen</td>
<td>Metal hydrides, in particular lithium hydride</td>
<td>Missiles and portable electronic equipment</td>
<td>High fuel cost, favorable weight ratio ca. 48/kg-kw-hr for entire cell including liquid oxygen or peroxide storage</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Commercial tank hydrogen</td>
<td>Lift trucks and tractors, signal equipment, stand-by power sources</td>
<td>Moderate fuel cost, high weight ratio ca. 14/kg-kw-hr for entire cell including compressed oxygen storage</td>
</tr>
<tr>
<td>Hydrogen and carbon monoxide</td>
<td>Conventional gasification of coal</td>
<td>Large scale power sources</td>
<td>Impure gases (CO, and sulfur compounds), fuel cost using Koppe's gasifier and oxygen ca. 9 mills/kw-hr</td>
</tr>
<tr>
<td>Hydrogen and carbon monoxide</td>
<td>Underground gasification of coal</td>
<td>Large scale power sources</td>
<td>Impure gases, less favorable economically in U.S. than conventional gasification</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Oil refineries (hydrogen produced in cracking and reforming operations)</td>
<td>Moderate sized power sources</td>
<td>Limited application because of restricted nature of fuel source, costs depend on other markets for this source of hydrogen</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Reforming of natural gas</td>
<td>Large scale power sources</td>
<td>Appears favorable in U.S. Southwest, fuel costs ca. 4 mills/kw-hr</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Electrolysis of water</td>
<td>Storage of electrical energy</td>
<td>Suggested as a method to relieve peak load problems, not of commercial interest at present</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Radiolysis and photolysis of water</td>
<td>Conversion of other energy forms into electrical energy</td>
<td>No information available</td>
</tr>
</tbody>
</table>

Table 1 Fuel Gas Sources
Fuel Oils (FO) and Fuel Containing Explosives. Any liquid or liquefiable product used for generating heat or power, exclusive of oils with flash point below 100°F or oil burning in cotton or wool wick burners (such as kerosene). Oils used in the US may be subdivided into the following grades:

- **No 1**: liquid with fl p 100°F, boiling range 400 to 625°F; used in vaporizing or pot-type burners
- **No 2**: liquid with fl p above 100°F, distilling at ca 675°F; used for general purposes in domestic heating
- **No 3**: not known
- **No 4**: viscous liquid with fl p 130°F; used in industrial burners not equipped with preheaters
- **No 5** and **No 6**: are solid which must be liquefied by preheating before burning; used in burners equipped with preheaters. They are sometimes referred to as bunker fuel oils and are used in ships, locomotives and industrial power plants

Fuel oils are used extensively in War Plants, as, for example, a typical WWII TNT manuf plant used them in sulfuric acid concentrators, in quadruple effect evaporators of TNT, red waste water, in rotating drums for incineration of the so-called "thick liquor" and as fuel for heating boilers

- Some fuel-oils are used for driving internal combustion engines, such as **Diesel Motors**, invented by Ger engineer Rudolf Diesel (1858–1913). Diesel oil is a heavy fuel in which combustion starts by spontaneous ignition due to compression, instead of spark-plugs used in gasoline motors

Fuel oil and other types of fuel oils are used together with oxidizing materials (such as nitrates, chlorates or perchlorates) of which the most important mixtures are **AN–FO** (Ammonium Nitrate–Fuel Oil). These mixtures usually contain 5–6% fuel oil and can be prepared on-site or by packing AN first in a borehole, followed by oil. FO's are also used for coating grains of hygroscopic materials, such as Amm or Na nitrates

---

**Fuel Element.** Any material which may undergo the appropriate reaction and be the source of energy in a fusion or fission nuclear reactor is known as **nuclear fuel**. At the present state of technology such fuels are uranium, thorium or plutonium, either as natural materials or enriched or synthesized isotopes of these elements. They are used as solids or as solids (metals, oxides, or carbonates) shaped as plates, rods etc and known as **fuel element** (fuel plate or fuel rod)

US Specifications for fuel oils are listed in Refs 5 to 9. AN–FO expls are listed in Addnl Refs


F) H. Mager, FrP 1370801 (1964) & CA 62, 3877 (1965) (The disadvantages of on–site mixing of AN & FO can be avoided if the AN (93–96 parts) is knaded in a mixer with colloidal grease (1–4 parts), such as naphtha or petroleum thickened with stearic acid and glycerol which contains 1–4 ps powd Al, B, Bi or Mg) G) S. Hodgson, CanP 707268 (1965) & CA 63, 1650 (1965) (Blasting expls prepbd by mixing 6 parts of a light FO with 94 ps high density micropills and adding 5 ps of hydrotatable salt, such as nitrates of Mg, Al, or sulfates of Ca or Mg) H) T. Seguiti, IndMinerai (Rome) 16, 289–98 (1965) & CA 64, 7959 (1966) (Uses and properties of AN–oil mixts) I) F. Mezner & S. Ura, Rudasko–MetSbornik 1965 (3–4), p 327 (In Slovenian) & CA 65, 6987 (1966) (Expl mixt of AN 94.5 & FO 4.5%, called Nitrol: ppt of sp gr 1.0 which can be used cartridge or loose) J) J. Dusek & R. Mecir, Rudy (Prague) 14 (3), 72–4 (1966) & CA 65, 5292 (1966) (The Czechoslovakian expl DAP–1, for use in overcast large diam boreholes (>75mm), is prepbd by simultaneously adding 95% fuel oil to the borehole directly before blasting without any special mixing) K) K. Sumpfl, Glueckauf 102 (15), 765–72 (1966) & CA 65, 11319 (1966) (It is spelled Glueckauf) (Historical review of the expls, based on mixts of AN with org liquids, preferably Diesel oil) L) G. Hoferstorfer & R.O.R. Oscarsson, SwedenP 202595 (1966) & CA 66, 57493 (1967) (Blasting expl consisting of AN with 5–6% mineral oil are conveyed into a borehole either by compressed air or in a plastic-foil hose) M) J. Kaemmler & J. Ruhmannseder, Rudy (Prague) 14, 139–42 (1966) (Development of AN–FO expls Dekammon–1 and Dekammon–2 at the potash mines of E. Germany). Their compns are not given in CA 67, 45698 (1967) N) Ch.H. Grant & Th.E. Skyhouse, USP 337799 (1968) & CA 69, 20841c (1969) (A 2-component expl of which the 1st mixt consists of AN 94 & fuel oil 6%, while the 2nd mixt consists of AN 37, Al (40–100 mesh) 10, formamide 10, water 12, Karay gum 1 & Na nitrate 10%. The 1st mixt can be located in the borehole either adjacent to the 2nd mixt or be surrounded by it) O) Fernando S.S. Sobral, Tecnica (Lisbon), 1968 (377), 431–46 (Portug) & CA 70, 1311 (1969) (A review with 28 refs of properties and methods of application of AN–FO expls) P) B.N. Kukib, Vzryvnoye Delo 1968 (65/22), 269–76 & CA 71, 31945g (1969) (Comparison of effectiveness in blasting of several Russ expls, showed that Anfex (expl contg porous granu-
lated AN & Diesel oil) is superior to BA-62
(expl cong nonporous AN & Diesel oil)]
Q) T. Yamagi et al, JapanP 6918573(1969) &
CA 71, 11402p(1969) [Porous AN granules for
use in AN-FO expls, were prepd by spraying
high-density particles with 0.3-3.0 wt% aq
soil of higher fatty acid salts (such as alkyl-
benzenesulfonates or alkylaminocetates),
followed by rapid drying at 100°] R) F.
Rzepecki, Cement-Wapno-Gips 5, 148-51
expl Solotrol prepd by mixing in-situ in open
pit mining of AN 94-96 with mineral oil
6-4%) S) John McKee, BritP 1171536(1969)
& CA 72, 57360h(1970)(AN-FO expls were
prepd in a device described in Ref 563 of
Vol 5, pp D1712-L & D1713-L) T) A.I.
Tevzadze et al, VzryvnoyeDelo 1969(67/24),
149-53 & CA 73, 27144u(1970)(Russ AN/FO
expl Ildanit cong 2% Diesel oil was more
suitable for blasting agate cong rocks than
expl cong 5% oil because it caused less dis-
integration of rock-surrounding agate. Ildanite
95/5 was, however, more effective because of
superior penetrability of oil into AN) U) M.
Barbaste, FrAddn 94808(1969) to FrP 1541657
(CA 71, 51826x); CA 73, 57647c(1970)(An expl
cong AN100, fuel oil 3, naphthalene 2 & Al
4.2g was superior to that cong AN 100, fuel
oil 3 & naphthalene 3g) V) J.H. Paasch,
SArfricanP 68 05568(1970) & CA 73, 89729x
(1970)(Booster comps for initiation of AN-FO
and aq slurred expls contain PETN 50, DNT
10, NC 2, DBuPh 15, oat-hull meal 2 & AN
21%) W) R.E. Schultz & P.H. Rydland, USP
3540953(1970) & CA 74, 33218h(1971)
(Blasting comp consisting of prilled AN
98-96, Mg nitrate or Ca nitrate in small amts,
hydrocarbon oil 1.2-7.2 & carbon black 1.2-
7.2 parts) X) L. Nemeth, BanyaszKutIntez-
Kozlem 1970, 14(3), 57-65(Hung) & CA 75,
8057c(1971)(Improving AN-FO mixes & blast-
ing slurries in Hungary) Y) N.W. Monroe,
SArfricanP 6904554(1970) & CA 75, 65773s
(1971)(Expl comps for borehole-blasting
agents) Z) J.G.P. Goliger, GerOffen
2021702(1971) & CA 75, 65776a(1971)(Cord-
type expl for underground construction & mining
consists of AN granules soaked with extra-
light fuel oil. Up to 35% wood powder may be
added as a diluent)

Fuel Oils, Analytical. The following determinations were made at US War Plants during
WWII: 1) Specific Gravity 2) Moisture
3) Insolubles 4) Flash Point and 5) Pour
Point Tests
A detailed description of these tests is
given by Clift, Fedoroff & Young in "A Manual
for Explosives Laboratories", Vol 3, Suppl
No 2, Chap XIX, pp 1 to 5, Lefax, Inc, Phila
(1943)
More recently the tests are described in
StemethodsChemAnalysis 2B(1963), Chapter
40, "Petroleum and Petroleum Products", pp
1913-2033. Most of these methods are Stan-
dards of the American Society for Testing and
Materials

Fuel-Oxidizer Type Propellants. See Com-
posite Propellants in Vol 3, pp C464-L to
C474-L

Fuels by Hydrogenation of Cool & Coal Tar.
See under "Coal Processing or Obtaining More
Valuable Products" in Vol 3 of Encycl, p
C379 and also in Refs 3, 7 & 11 listed on p
C380-R

Fugacity. Accdg to Hackh's (Ref 1), it is the
escaping tendency in a heterogeneous mixture,
by which a chemical equilibrium responds to altered conditions. In a dilute soln obeying the
gas laws, the fugacity equals the osmotic
pressure. In other solns it is the value of the
pressure for which these equations are still
valid

Accdg to Ref 2, fugacity is a quantity
which measures the true escaping tendency of
a gas, a sort of idealized pressure. If primes
and double primes refer, respectively, to an
ideal gas and a real gas, then:
\[
dF' = V'dp = RTdlnp, \text{ and } \n\]
\[
dF'' = V''dp = RTdlnf, \text{ and } \n\]
where $dF$ is a change in free energy, or chemical potential, produced by a change in pressure, $dp$; $V$ is the volume of the gas at the absolute temperature $T$, $f$ is its fugacity and $R$ is the gas constant. Cook (Ref 3) describes a method of calculating fugacities and the calcn of equilibrium concentrations using ratios of fugacities

Refs: 1) Hackh's Dict (1944), 359 2) The Van Nostrand Chemist's Dictionary, NY (1953), 308 3) Cook (1958), 381 (See next item)

**Fugacity Determinations of the Products of Detonation** were determined by M.A. Cook for PETN, RDX, LNG, Tetryl and 60% Straight Dynamite, by employing the equation of state derived from the hydrodynamic theory and observed velocities of detonation. The so-called reiteration method was developed for solving simultaneously as many equilibria as is necessary to determine completely the composition of the products of detonation. Detailed description, together with 14 references is given in the original article:


**Fugacity of Products.** See Vol 4, p D351-L.

**Fugasnost' or Fugasnoye Deystviye** (Rus). Acdg to definition given in Blinov’s, “Kurs Artillerii,“ (Artillery Course), fugasnost' is the destructive action caused by the gases of an explosive and is expressed by the cubic centimeters of expansion products in the cavity of a lead block by exploding a 10g sample. The test is a modification of Trauzl Test, used for det of power of exps (See Fugasnyi Snariady) Ref: Fedoroff et al, PATR 2145(1955), p Rus 7-L.

**Fugasnyi and Oskolchno-fugasnyi Snariady** (Projectiles). Fugasnyi [Abb: Rus letter φ (F)]. It is a high-explosive shell with thin walls and very large bursting charge. It possesses high heaving action and blast effect and for this reason is used against installations as demolition shell

Oskolchno-fugasnyi [Abb: Rus letters Оφ (OF)]. It is a fragmentation—HE shell with wall thickness and bursting chge intermediate between fugasnyi and oskolchny shells. It can be used either against personnel or installations.

Oskolchny Shell (Abb O) is a HE fragmentation shell with thick walls and small bursting charge. It is an antipersonnel (A/P) shell

Other Russian projectiles are:

Broneprobivnyi [5(φ)], corresponds to Amer AP (armor-piercing) shell

Broneproshibayushchii [5Π (θ)] means “burning-thru-armor” and corresponds to Amer shaped-charge shells used against the tanks (HEAT Shells)

Granatnyi [Γ (≬)] corresponds to Amer CP (concrete-piercing) shell

Dymovyj [Π (θ)] — Smoke Shell

Zasibigateli'nyi [3(Z)] — Incendiary (I) Shell

Signal'nyi [C(S)] — Signal or Illuminating Shell

Khimicheskii [X(Kh)]. Chemical (or gas) Shell

Shrapnel' [ω(Sh)] — Shrapnel Shell

Agitatsionnyi: [A(A)] — Propaganda Shell

Ref: Fedoroff et al, PATR 2145(1955), p Rus 16 and Figs on pp Rus 14 & 15

**Führer** of Wien was the first to use pulverized metallic Al as an ingredient of expls. He took British and Belgian patents in 1900

Ref: Daniel (1902), 310

**Führer's Silicium Explosive.** Mining expl patented by J. Führer in 1904. It was the first expl to contain silicon. Its composition was Amm nitrate 77, DNT 10.5, Si (crystalline) 10 and wood flour. It was not powerful and its oxygen balance was negative

Ref: R. Sartorius, MP 34, 211 (1952)

**Fulgor Powders.** Smokeless powders patented in 1895 in England by Ungania, existed in
several varieties, as for example: Fulgor A (suitable for military purposes): Endecahydonitrocellulose (or endecahydonitrocellulose) 75.8, Hexanitromunnite 22.7 & paraffin 2 parts. Aniline black 0.05 pts was added. Gelatinized by means of ethyl acetate. Fulgor B (suitable as sporting powder): Endecahydonitrocellulose 100 & K₄Fe(CN)₆ 0.05 added. Gelatinized by means of ethyl acetate. Fulgor C (suitable as sporting powder): Hexahydonitrocellulose 64.5, Hexahydonitrocellulose 16.2, KCIO₃ 12.1, Ba(NO₃)₂ 6.4, paraffin 0.8 and K₄Fe(CN)₆ 0.05 added. Preparation of endeca- and hepta-nitrocelluloses, as well as of Hexanitromunnite, is given in Ref 1. Refs: 1) E. Ungania, Brit P 12325 (1895) & JSCI 15, 376 (1896) 2) Daniel (1902), 311-12 3) Fedoroff & Clift 4 (1946), 37

Fulgorites. Accord to Daniel (Ref 1) & Gody (Ref 2), they were Hungarian Dynamites consisting of NG 60-90 absorbed by a mixture of wheat flour & Mg carbonate 40-10%. Another Fulgorite was patented in 1900 in France by Serrat. It contained Nitrocompounds of cresol or naphthalene. Refs: 1) Daniel (1902), 313 2) Gody (1907), 362 3) Fedoroff & Clift 4 (1946), 37

Fuller's Earth. A variety of clay-like materials containing silicates of Fe and Mg which have natural adsorptive powers; have been used in industry for many purposes, among them as absorbent for NG in Dynamites. Refs: 1) Davis (1943) 195, 216, 218, 332 & 336 2) Fedoroff & Clift 4 (1946), 37 3) Cond-ChemDict (1961), 517-R

Füllung or Fülpulver (Fp or FP). German name corresponding to expls used as fillers for bombs, shells, grenades or mines. They serve as bursting charges. A complete list of such expls is given in PATR 2510 (1958), pp Ger 46-R to Ger 48-R, under FILLER

Fulmenit (Ger). Permissible expls, such as a) AN 86.5, NC 4.0, TNT 5.5, charcoal 1.5 & paraffin oil 2.5% (Refs 1, 3 & 4) and b) AN 82.5, NC 4.0, TNT 11.0, charcoal 1.5 & paraffin oil 1.0% (Refs 2 & 4) (See also Wetter-Fulmenit). Refs: 1) Gody (1907), 595 2) Marshall (1917), 391 3) Barnett (1919), 113 4) Clift & Fedoroff 2 (1943), 0 F3 5) PATR 2510 (1958), p Ger 53-L

Fumibois. A French name for Nitrolignin or Nitratred wood which was prepd by nitration of sawdust. Ref: Daniel (1902), 313

Fulmicoton. Accdg to Patterson's French-English Dictionary it is Guncotton, while Fulmicoton soluble is Pyroxylene. Guncotton has N content 13.47% and its formula corresponds to Endecanitrocellulose, C₂₄H₂₉O₁₁(ONO₂)₁₁. Its N content is slightly higher than that for CP₁ (Coton-poudre No 1), listed in Vol 3 of Encycl, p C551-R. Pyroxylene contains about 12% N and it is listed as CP₂ (Coton-poudre No 2) on p C551-R

Fulmicoton de Faversham or Tonite. Under these names are known expls consisting of Fulmicoton & Ba nitrate with or w/o other ingredients. The following compus are listed by Daniel (Ref): Tonite No 1, patented in England in 1874 by Trench, Faure & Mackie contd Fulmicoton 51.6 & Ba nitrate 48.4%; white pdr Tonite No 2 contd charcoal as the 3rd ingredient; grey pdr Tonite No 3, patented by Trench contd Fulmicoton 14.55 to 19.0%, m-DNBz 13.2 to 13.0 & Ba nitrate 72.25 to 68.0%. It was manufd in England beginning in 1889 and used extensively for underwater blasting and as a bursting chge for torpedoes. It was manufd in the US by the
Fulminates

Fulminates are salts of fulminic or para-acyanic acid (qv), which is isomeric with isocyainic acid. Fulminates should not be confused with Fulminating Compounds (qv). Structural formulas of fulminic acid and its salts have not yet been definitely established. The free fulminic acid has not been isolated from its salts, as it undergoes polymerization very rapidly both in aqueous and in ethereal solns. The acid and its metallic salts, $\text{M}($ON$\equiv$C$\equiv$O$\text{)}_n$, are very poisonous and explosive. The best known and most used salt is Mercuric Fulminate (qv).

A historical background of fulminic acid and salts was given in the book of R. Scholl, "Entwicklungsgeschichte der Knallsäure", Habilitat, München & Leipzig (1893) and by M. Giua in "Trattto di Chimica Industriale", 6(1), UTET, Torino (1959), pp 415–19

Fulminic Acid (qv) was prep'd and identified in 1800 by E. Howard, who also prep'd and identified MF, first prep'd (but not identified) in the 17th century by J. Kunkel von Löwenstem. Silver Fulminate was first prep'd in 1798 by L. Brugnatelli.

More thoroughly, HON$\equiv$C or simply HONC, and its salts were investigated in this century by Wöhler, Martin et al (Refs 2, 3 & 10).

Alkali Fulminates, MONC of Cs, K, Na & Rb were prep'd and investigated before WW1 in Warsaw by Hackspill & Schumacher (Ref 18). The Na salt was prep'd in 1921 by A. Langhans (Ref 6). It was found that all alkali fulminates have similar properties, such as: they all can be dissolved in methanol crystallizing on its evapn, probably in the hexagonal system. When dry, they were easily detonated by feeble rubbing or by heating. They easily formed expl double salts with MF. For example RbF–MF easily exploded at 45°. Description of K and Na salts are given separately.

Ammonium Silver Fulminate, $\text{Ag(NH}_4\text{)(ON)}_2$; mw 209.96, N 20.02%; crysts (alc+eth); unaffected by light; mp = expl on heating; sl sol in w; sol in alc. Can be prep'd by the action
of Amm iodide on SF. It is a less violent expl than SF [Ref 1, p 777]

**Cadmium Fulminate, Cd(ONC)₂**: mw 196.45, N 14.26%; wh crs, mp - expl at 215° in 5 sec; sol in w & methanol; sl sol in ethanol. Can be prepd by shaking Cd amalgam with MF dis- solved in methanol. Heat of deton 470 cal/g. It is a powerful expl resembling MF in its props. It is stable when kept dry but decomp in the presence of moisture. Smallest amts which cause detonation of: Tetryl 0.008 g, PA 0.05 g, TNT 0.11 g, TNAisol 0.26 g & TNXylene 0.35 - [Ref 1, p 376 & Ref 23, pp 407 & 411]

**Copper (I) Fulminate or Cuprous Fulminate.**
See Vol 3 of Encycl, p C520-R and Davis (Ref 23, p 407) gives smallest amts of Copper Fulminate which cause detonation of: Tetryl 0.025 g, PA 0.08 g, TNT 0.15 g, TNAisol 0.32 & TNXylene 0.43 g

**Copper (I) Fulminate Explosive Complexes**, listed below are described in Vol 3 on pp C520-R & C521-L:
- Copper (I)-barium Fulminate, Ba[Cu(ONC)₂], 4H₂O
- Copper (I)-calcium Fulminate, Ca[Cu(ONC)₂], 4H₂O
- Copper (I)-dicopper (I) Fulminate, Cu₂[Cu₂(ONC)₄]; 2H₂O
- Copper (I)-disodium Fulminate, Na₂[Cu(ONC)₂]; 3H₂O
- Copper (I)-sodium Fulminate, Na[Cu(ONC)₂]
- Copper (I)-strontium Fulminate, Sr[Cu(ONC)₂]; 2H₂O

**Mercuric Fulminate or Mercury Fulminate**
(Fulminate de mercure in Fr; Knallquecksilber in Ger; Fulinato di mercurio in Ital; Fulminato de mercurio in Spain; Gremschaya rtv' in Russian; and Raikō or Raisan suigin (Thunder Mercury) in Japan). Hg(ONC)₂. Structural formula not established. Pepin Lehalleur (Addnl Ref J, p 141) proposed Hg(ONC)₂ and that of Scholl

H₈ON: C = H₈ON: C; mw 284.65, N 9.85%, OB to CO₂ -17% & to CO -5.5%; hydrate Hg(ONC):₄H₂O (crystd from w) (Ref 23, p 410) has mw 293.64, N 9.55%. Anhydrous form (crystd from alc) is white to grey crs of density 4.42-4.43, exploding at 210° in 5 sec; its apparent density is 1.55 to 1.75; when subjected to pressures of 3, 10 20 & 50 thousand psi, densities of 3.0, 3.6, 4.0 & 4.3 are obt'd. Pressures of 25 to 30 thousand psi (or more) cause the desen- sitization of MF to the extent of becoming dead-pressed. Such material merely ignites and burns when subjected to contact with flame, but it can be detonated if it is covered with a layer of loose or sl compressed MF and ignited

MF is sol in 1 liter of w to the extent of: 0.71g at 12°, 1.74 at 49° and 7.7 at 100° (Ref 23, p 410); only sl sol in cold ethanol.
It decomp in the presence of aq solns, chlorides, carbonates, hydroxides etc. Due to the presence of small amts of Hg, formed by exposure of MF to light or elevated temps, it readily forms amalgams with C, brass or bronze, thus components cong these metals must be protectively coated if used with MF.

MF is also sol in pyridine and aq NH₃ or K cyanide and can be recovered from pyridine by adding w and from NH₃ & cyanide solns by adding acid

MF reacts with concd HCl to form hydroxylamine, H₂N.OH, & formic acid, HCOOH, and it reacts with Na thiosulfate in aq soln to form Hg tetrathonate, accdg to the equation:

Hg(ON:C)₂ + 2Na₂S₂O₃ + H₂O →
HgS₄O₆ + 2NaOH + NaCN + NaNCO

This reaction can be used for det of purity of MF

**Preparation of MF**

MF was first prepd in the 17th century by Swedish-German alchemist Baron Johann Kunkel von Löwenstern living from 1630 to 1703 (Hackhe's Dict gives 1638 as date of birth). He obt'd this dangerous expl by treating mercury with nitric acid and alcohol. The method was described in the book of Kunkel published in 1716 after his death. This book is listed and the prep is briefly described by Davis (Ref 23, p 404) and Pérez Aza (Ref 24, p 541). A brief biography of Kunkel is given in Ref 24, p 541 and in Hackhe's (1944), p 474
As no use of Kunkel's expl was found by him and by other alchemists, the compd became forgotten until Edward Howard of England rediscovered it in 1799–1800. He described its prep in Phil Trans Roy Soc 1800, 204, and his method of prep is given in Davis (Ref 23, p 404). Howard examined props of MF but it does seem that he proposed its use as a percussion initiator of BkPDr. This honor belonged to the Scottish Clergyman Alexander Forsyth who patented in 1807 in England such a device. The history of this and of later development of MF initiators and of various types of cartridges is described in Vol 5 of Encycl, p D755-R & D756-L. More important application of MF was in A. Nobel's Blasting Cap invented in 1867. This cap was used for detonation of NG and Dynamite (See "Fulminate Blasting Cap" in Vol 5 of Encycl, p D1586-R).

Besides describing Howard's method, Davis (Ref 23) described on p 406 a laboratory method using 5g of Hg. We found that it is safer to start with 2g Hg and to proceed as follows:

**Laboratory Preparation:**

1) 2g of pure redistd Hg is added to 10ml of pure nitric acid (sp gr 1.42) in a 100-ml Erlenmeyer placed under a hood and left there without agitation until complete dissolution
2) The resulting soln of Hg nitrate in excess of acid is poured into 20ml of 90% alcohol contd in the 2nd 100-ml flask, which is placed in a trough of running water located under a hood and behind a safety glass or plastic. A vigorous reaction results, accompanied first by evolved white fumes, then by brownish-red and finally again by white fumes. At the same time crystals of MF deposit on the bottom of the flask. After about 20 mins, the fuming ceases and the contents of flask are poured into a 250-ml beaker congr cold w. After the bulk of acid w has been removed by decantation, the crystals are transferred onto a Büchner connected with suction flask to be washed w w until it becomes neutral to litmus. This gives about 3.4g of crude greyish (due to presence of small amt of metallic Hg) product, which corresponds to good-grade commercial product. It can be stored under water until a sample is required for expl purposes. Then part of product is dried in a desiccator.

MF has been thoroughly investigated especially before and during WWI by Col Solomon of Russia (Addn Ref A). Other investigators were Liebig, Chandelier, Bechmann, Tschelzof (Chet'csoff), Wöhler, Martin, Langhans & Stretbacher (Ref 17, p 141).

Pepin Lehalier (Ref 17, pp 143–44) describes Liebig's and Chandelier's methods of manuf which have been used in France.

Pérez Ara (Ref 24, p 545) briefly describes an industrial method using 1 kg of Hg, 9kg of nitric acid and 8–12kg of alcohol. He also describes on p 546 industrial methods of Bechmann, de Bruyn and of the Troisdorf Fabrik of DAG in Germany. All of these methods differ only slightly from the US method described below. The method of de Bruyn, instead of adding acidic Hg nitrate to alc, bubbles vapor of alc thru the soln of Hg in nitric acid. The reaction proceeds at 70°. In the method of the Troisdorf Fabrik, small quantities of Zn & Cu are added during dissoln of Hg in nitric acid (2g of Zn & 3g of Cu per 500g Hg and 5kg nitric acid). This method is claimed to give white MF.

In all methods, except that of Troisdorf, the resulting MF is of greyish color due to the presence of small quantity of free Hg. Such MF is not suitable for loading into caps made of Cu or Cu-congr alloys such as brass or bronze. This is because free Hg attacks Cu forming a Cu amalgam, and this will react with MF to form Cuprous Fulminate which is less stable and more sensitive than MF.

In order to avoid the formation during manuf of greyish MF, Solonina proposed adding 1.5g of CuCl₂ per each 50g of Hg during its dissoln in nitric acid, whereas Adler proposed dissolving in nitric acid a small quantity of Zn before adding Hg (4g Zn per 50g Hg).

Accdg to Davis (Ref 23, p 407), MF can also be prepd by replacing ethanol with acetaldehyde, paradehyde, metaldehyde or dimethyl- and ethylacetal. Another method consists of
treating the Na salt of nitromethane with an aq.
soln of HgCl$_2$ at 0° to form a wph ppt of mer-
curic nitromethanate. This gradually becomes
yel and when digested with warm dil HCl yields
MF

MF can also be manufd by Biazzi Process.
Since it is not described in Vol 3 of this Encycl,
pp C501ff, under "Continuous Methods for Manu-
facturing Explosives" it is suggested that
info be obtained directly from Dr Mario Biazzi,
Ing, Vevey, Switzerland

**Manufacture of MF in the USA**

The following method used to be employed at
Picatinny Arsenal and probably is still used
in oth: US plants because a similar method is
described in Ref 32 and Ref 35 (1967)

In order to produce MF of quality comply-
ing with requirements of US Military Specifi-
cation JAN-M-219, all raw materials: mercury,
nitric acid and ethanol should be of high purity
Procedure:
1) About 1 lb of pure, redistilled mercury was
carefully added to an open earthenware vessel
(or a 5 liter flask) contg 8 to 10 lbs nitric acid
(d 1.4), which was in excess of the amount re-
quired by the equation: $3\text{Hg} + 8\text{HNO}_3 \rightarrow
3\text{Hg(NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O}$

A large number of such charges were usu-
ally prepared and allowed to stand overnight
until the Hg was completely dissolved

2) A 10 gallon Pyrex flask or balloon, contg
8–10 lbs of 95% alcohol and fitted with a re-
flux condenser, was placed on a rack in a
trough with running cold water. This installa-
tion had to be either outside or in a building
provided with an exhaust system

3) With the condenser removed, the acidic soln
of mercuric nitrate was poured into the alcohol
and then the condenser was replaced. After
about 2–3 minutes, a violent reaction started
and the liquid boiled with evoln of white fumes.
Most of these fumes were recovered by the con-
denser, however. As the reaction approached
the end point, the color of the fumes usually
changed to brownish-red due to the decomposi-
tion of nitric acid by heat. As this heat might
also decompose the MF (which had just formed),
a small quantity of dilute alcohol had to be
added at this point to moderate the reaction.
The reaction normally lasted about 1½ hours
and MF crystallized

5) After cooling the charge in the flask, it was
dumped onto a cloth screen and the crystals
of MF washed with cold running water to re-
move excess nitric acid and impurities known as "fulminate mud"

6) The washed MF was then drained and packed
into cloth bags which were stored in tanks of
water until required for use

For shipment, the bags were packed in
barrels of wet sawdust

7) When required for use, the MF was removed
from the bag and spread on a cloth in a thin
layer and dried in a special building where the
temp was carefully regulated to 43°(110°F)

8) The acid mother liquor and the water wash-
ings were neutralized with alkali, evaporated
to recover the alcohol and treated to recover
any Hg or its salts

The usual yield was about 1.25 parts of
slightly greyish MF per one part of Hg. Its
purity was 98–99%, which corresponded to
usual commercial product (Ref 32, p 588 &
Ref 35, pp 7–5 & 7–6)

The intermediate products of oxidation an
and nitration involved in the prep of MF are
as follows:

CH$_3$CH$_2$OH $\rightarrow$ CH$_3$CHO $\rightarrow$ CH$_3$(NO)$_2$CH $\rightarrow$ CH$_2$(NO)$_2$CHO
Ethanol Acetaldehyde Nitrosoglyco-
 Isorosineglyco-
taldehyde
taldehyde

CH$_3$(NO)$_2$COOH $\rightarrow$ C(NO$_2$)$_2$(NOH)$_2$COOH $\rightarrow$ C$_2$H$_5$CH$_2$(NOH)
Isonitrile iso-
Nitrosoritrile
 Nitrosalicylic acid
 Isorosalic acid
 Isorosalicylic acid

C$_2$(NOH)$\rightarrow$Hg(ONO)$_2$
Fulminate Mercury
 acid fulminate

(Ref 35, p 7–6 & Ref 23, p 407)

Accdg to Ref 35, p 7–6, the above commer-
cial product can be purified to 99.75% by dis-
solving it in concd Amm hydroxide, filtering
the soln, cooling the filtrate, and reprecipita-
ting slowly, adding concd nitric acid with
rapid agitation, while keeping the temp below


35° The pptd pure MF is washed with distilled water until free of acid. The yield is 80-87%.

According to Ref 17, p 146, a fairly pure MF can be obtained by rinsing the crude MF (packed on two layers of filter paper placed in a Büchner) with several portions of 80-85% ethanol, thoroughly removing by suction each rinsing and testing it by diluting with water. The completion of rinsing is indicated by absence of turbidity on addition of water.

There are two other methods of purification listed in Ref 17, p 146. Steiner dissolved crude MF in concd aq soln of KCN followed by adding concd HCl and washing the resulting ppt with water. Solovine dissolved 1 part of crude MF in 7 parts of pyridine, filtered the soln and poured it into 100 parts of cold water.

The size of the crystals of MF is an important factor. While very finely divided MF consisting mostly of fragments of crystals is undesirable because the crystals might contain large amount of impurities, thus diminishing the efficiency of MF, too large crystals are also not desirable because they are very sensitive to friction and shock. Therefore, the US Military Specifications such as JAN-M-219, provide a certain minimum and a maximum size for crystals. Fig F24 reproduced from Ref 35, p 7-5, shows typical crystals magnified 125 times. The Fig 94 on p 409 of Ref 23 (not reproduced here) shows crystals for use in primer comps, magnified 35 times.

If crystals of MF are so small that they look like colloidal particles, the material is very difficult to initiate even if it is nearly 100% pure.

Explosive and Other Properties of MF (Refs 5, 7, 9, 11, 12a, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 35, 37 & 38) (Also Addn Refs F, R, S, T & X):

- **Activation Energy**: 29.8 kcal/mol; Induction Period 0.5-10 sec (Ref 34)
- **Ballistic Mortar Test**: Not found
- **Behavior Towards Flame**: When a single crystal is ignited, it burns rapidly with a flash, but does not detonate; when a layer of crystals is ignited, a high order of detonation takes place.
- **Brisance by Sand Test in 200g Bomb**: 0.4g MF crushes 17.9 to 23.4g sand compared with 48g for TNT, which means 27.3 to 59% of TNT. It is greater than LA and smaller than DADNPh.
- **Compatibility with Metals**: When dry — reacts rapidly with Al & Mg and slowly with Cu, Zn, brass & bronze. When wet — reacts immediately with Al & Mg and rapidly with Cu, Zn, brass & bronze. Dry or wet does not attack iron or steel (Ref 34).
- **Destruction of MF can be achieved by adding it, with stirring, to at least 10 times its weight of 20% Na thiosulfate. Some poisonous cyanogen gas may be evolved** (Ref 34).
- **Deterioration of MF in Storage**: At 10-20°C, 30-35°C, 50 and 80°C. See under Stability of MF in Storage.
- **Detonation Rate for Pressed MF**: 3500m/sec at d 2.0, 4250 at 3.0 & 5000 at 4.0 (Ref 34)
- **Electric Spark, Sensitivity to**: MF is capable of being ignited by a spark from a person charged to less than 5000 volts, a condition that is possible in plant operations. Brown et al (Ref 27) give for Sensitivity to Electrostatic Discharge 0.025 joules (Ref 34)
- **Explosion (or Ignition) Temperature**: 210°C (in 5 sec) 239°C in 1 sec & 263°C in 0.1 sec (no capsule used) (Ref 34)
- **Flammability Index**: Not found.

*FIG F24 MF Crystals*
Friction Pendulum Test. Expl on fiber & steel shoes (Ref 34)

Gas Volume Evolved on Explosion = 243cc/g
(Ref 34)

Heat of Combustion. 938cal/g
Heat of Explosion. 427cal/g
Heat of Formation. 226cal/g

Heat Test at 100°. Explodes in 16 hrs (Ref 34)

Hygroscopicity. Gains 0.02% at 30% RH
(Ref 34)

Impact Sensitivity Tests. Bur Mines App - 5cm for 2kg wt (20mg sample); Pic Arsen App - 4 inches for 1 lb wt (30mg sample) (Ref 34). It is more sensitive than LX of LSulfonate (Ref 35).

Initiating Efficiency of MF. Although MF is not as efficient an initiator as LA or DAZDNPh, it is satisfactory when used in conjunction with Tetryl, RDX or PETN boosters. During the 1st half century of MF was almost the only initial detonating agent used and its efficiency was considered satisfactory (Ref 35).

Initiating Efficiency. Grams of MF Required to Give Complete Initiation: 0.25 for TNT, 0.20 for Tetryl, 0.19 for RDX and 0.17 for PETN (Ref 34). Also Expl D 0.85, TeNAntline 0.25 and PA 0.21. Rather different values are given by Davis (Ref 23, p 407): Tetryl 0.29, PA 0.30, TNT 0.36, TNAntline 0.37 & TXylene 0.40g.

Initiating Sensitivity to Electrostatic Discharge. See under Electric Spark; Sensitivity to International Heat Test (75%). Loss in wt in 48 hrs 0.18% (Ref 34).

Loading Into Blasting Caps pressed at 3000 psi (Ref 23, p 410)

Plate Dent Test - not found

Power (or Strength) by Trauzl Lead Block

Test. 37 to 50% TNT (Addnl Ref T); 51%
(Refs 12a & 34). It is more powerful by Trauzl Test than LA (Ref 35).

Rate of Detonation. See Detonation Rate

Rifle Bullet Impact Test - not found

Sand Test. See under Brisance

Sensitivity to Electric Spark or to Electrostatic Discharge. See under Electric Spark

Sensitivity to Initiation - not found

Sensitivity to Pressure. When pressed at pressures in excess of 25000psi, MF will become dead-pressed, which means that it will not detonate either by flame, percussion or stab action. When such MF is ignited by heat or flame (as happens in electric detonators), it will burn but not detonate. However, it is possible to detonate the dead-pressed material by means of a strong Blasting Cap or by covering it with loose or sl pressed MF and then igniting the ensemble. In these cases, the velocity of detonation is even higher than for material that has not been dead-pressed (Ref 35 & Addnl-Ref T).

Specific Heat. 1.1cal/g/°C (Ref 34)

Stability. Accdg. to Ref 35, p 7-7, the relatively poor stability of MF has been its most disadvantageous characteristic and the main reason for efforts to replace it with a suitable substitute. The usual stability tests are only applicable to temps up to about 85° due to expln in a relatively short time at temps above 85°. When MF deteriorates, it is chiefly with the production of a non-explosive solid rather than gaseous products of decompn. It has been found that when its purity has been reduced to approx 92%, the initiating efficiency is practically destroyed, although the material will explode when ignited. When purity has been reduced to 95%, the stability is considerably impaired. (Note: Because of the poor stability of MF, it is no longer permitted by the US Military for service use).

Stability of MF in Storage. MF of purity 99.75% has been found to require storage at 50° for 24 months to become deteriorated to 92% (Ref 35, p 7-7). Different results are given in Ref 34, p 203, where MF of 99.75% purity deteriorated in 18 mos to 94.81%, while 98.86% deteriorated at the same period to 79.99%. Still other results are given in Table 7-3 on p 7-7 of Ref 35. Here, after storage at 50° for 8 months, the purity decreased to 95% and after 11 mos to 92%. When stored at 80°, purity dropped to 95% in half a day and to 92% in one day. When stored at 30-35° purity dropped to 95% in 1.7 years and to 92% in 5.8 years. When stored at 10-20°, a purity of 95% was
obtd in 7–8 years, while 92% was obtd after 9–10 years

*Stab Sensitivities at Various Densities* are
given in Table listed on p 202 of Ref 34

Storage. MF is stored under water and trans-
ported in a wet condition, because in the
dry state it is extremely sensitive to any
mechanical action. In winter it is stored in
50/50–water/methanol or water/ethanol.
MF should never be stored together with
any other expl(s) because the expln of even
a relatively small amt of MF present in a
dried state might cause the detonation of
wet MF and other expls. If any of the ma-
terial contg MF is spilled on the floor or
table, it must be destroyed by washing with
a satd soln of Na thiosulfate (Ref 35)

*Thermal Conductivity.* 1x10^-7 cal/sec/cm/°C
(Ref 34)

*Thermal Stability.* See Heat Test at 100°;
International Test (75°) and Vacuum Stabili-
ity Test at 100°

*Toxicity of MF.* Mercury and its compds
are of recognized toxicity. The handling
of MF is not unduly hazardous from a toxicity
viewpoint, but should be done with the mini-
 mum contact with the skin. Its dust should
not be inhaled and it has been recommended
that, in order to avoid undue toxicity, the
air in loading plant buildings should con-
tain not more than 0.1mg of MF per cubic
meter (Ref 35)

*Trauzl Lead Block Test.* See under Power
(or Strength)

*Vacuum Stability Test* at 100°. Explo-
des (Ref 34)

*Velocity of Detonation.* See Detonation Rate
*Volatility* – not found

*Uses of MF.* Until the invention of LA (Lead
Azide), MF was practically the only expl used
both in primers, blasting caps and detonators,
either by itself or in compns. When loaded
alone in blasting caps [also known as "com-
mercial (or nonmilitary) detonators"] it is
subdivided into eight numbers accdg to the
amt of MF contd in them: No 1 contains
0.30g, No 2 0.40, No 3 0.54, No 4 0.65,
No 5 0.80, No 6 1.00, No 7 1.50 and No 8
2.00g. The Table on p 414 of Davis (Ref
23) gives also external dimensions in mm.
This classification is international. Nos
6, 7 and 8 caps are the only ones manufd
in the US and the No 6 is the one most
commonly used (Ref 23, p 416). The ful-
minate in commercial and military detonators
was first modified by mixing it with BkPdr,
then with Knitrate, and later with K chlorate.
The chlorate mixts soon attained commercial
importance and by 1910 had largely displaced
straight MF. These were "single component
caps" which are described under "BLASTING
CAP" in Vol 2 of Encycl, p B185-R. They
are known in Gt Britain as "Plain Detonators"
as mentioned in Vol 4, p D737, under "Non-
military Detonators". Most commonly used
mixts have been MF/KClO₄–90/10 and 80/10
and weight by weight they are more brisant
than straight MF, when determined by Sand
Test (See Table on p 417 of Ref 23). These
mixts are more hygroscopic than straight
MF, but are cheaper and slightly safer to
handle and to load. Plain detonators have
been largely (but not wholly) displaced
during and after WWII by Compound Detona-
tors, which are described as "Compound
Caps" in Vol 2, p B185ff

There are in the USA two caps stronger
than No 8: 1) US Army Special Blasting Cap,
formerly known as "Special Army Engineer
Cap" (Vol 2, p B188-R) and "Western Big
Inch Cap" (Vol 2, p B186-R). They are
"compound caps" but do not contain MF

When MF is mixed with inert materials
and/or fuels, such as antimony sulfide
(Sb₂S₃), it merely rapidly burns (deflagrates)
and can be used (especially if some K
chlorate is also included) for igniting prop-
pellants, etc (See "Mercuric Fulminate and
Its Mixtures and Qualitative & Quantitative
Analyses", described after AddnlRefs for
SF)

As already mentioned, MF was largely
(and now wholly) displaced since 1930 by LA
(Lead Azide) and also by DAZdNPh (Diazo-
dinitrophenol), Cyanuric Triszide and L5t
(Lead Styphnate). This took place first in
Germany, than elsewhere in Europe and finally in the USA.

Specification Requirements and Tests of US Armed Forces are covered by JAN-M-219 (1945). It is discussed after AddnlRefs for SF (Silver Fulminate) under "Mercuric Fulminate and its Mixtures; Qualitative and Quantitative Analyses and Specification Requirements and Tests." 

**Mercuric Fulminate—Sulfur Compound,**

\[ \text{C}_2\text{H}_4\text{N}_2\text{O}_2\text{S} ; \text{mw} 121.14, \text{N} 23.13\% ; \text{crystals, mp} - \text{deflagrates below} 100^\circ; \text{sol in eth} & \text{alc; insol in water, was prepd by heating MF in abs ether & hydrogen sulfide} \]

Ref's: 1) *Beil 1, 723* 2) *Steiner, Ber 8, 1177 (1875); 9, 779 (1876)*

**Mercuric Pyrofulminate or Pyrofulmin.** An expld solid of empirical formula \[ \text{Hg}_8\text{O}_6\text{C}_8\text{N}_12 \]
with Hg content 77.77%; prep'd by P.Y. Narayana [Current Sci 13, 313–15 (1944) & CA 39, 4227 (1945)] by heating MF for 64 hours or until gases CO & CO₂ ceased to evolve. The compd was stable to at least 125°. It is identical with *Pyrofulmin* previously prep'd by A. Langhans [SS 17, 9-11, 18-21 & 26-28 (1922) & CA 16, 2603 (1922)].

Narayana presumed that 3 mols of MF polymerized in the manner characteristic of cyanogen compds and then decomposed according to equations:

\[ 3\text{Hg(ONC)}_2 \rightarrow \text{Hg}_8\text{O}_6\text{C}_8\text{N}_12 \] (hypothetical and unstable)

\[ 2\text{Hg}_8\text{(O}_2\text{N})_2\text{C}_2\text{N}_12 \rightarrow \text{Hg}_8\text{O}_6\text{C}_8\text{N}_12 + 3\text{CO}_2 + \text{CO} \]

**Potassium Fulminate, KONO,** mw 81.11, N 17.27%; crystals (from alc); very hygroscopic; sp gr 1.80; mp - expl; expl also by the action of flame. Can be prepd by shaking K amalgam with MF either in methanol or abs ethanol. Expln temp in 5 secs 225°

(See Ref 1, p [777] & Ref 23, p 411)

**Potassium—Silver Fulminate, KAg(ONC)₂,** mw 231.01, N 12.13%; mp - expl; sol in 8 parts of w. Can be prep'd accdg to Daniel (1902), p 319 by adding KCl to a hot aq soln of SF. When treated with dil nitric acid, a ppt of Acid Potassium Fulminate is formed which is also explosive (See also Ref 1, p 722 & Ref 23, p 413)

**Silver Fulminate (Fulminate d'argent in Fr; Knallsilber in Ger; Fulminato d'argento in Ital; Fulminato de plata in Span and Gre; mucheye Serebro in Russ), AgONO, mw 149.90, N 9.34%; wh crystals or amorphous aggregates; darkens on exposure to light; mp - expl at 170° in 5 sec (Ref 23, p 411); sol in w 0.0075 parts in 100ml at 13°, 0.018 at 30° and 0.25 at 100°; insol in nitric acid and is decompd by HCl.

**Preparation of SF**

**Caution:** Due to its extreme sensitivity to mechanical action, it should be prep'd only in very small quantities. When working in the lab, do it under a hood behind a safety glass or plastic, while for the plant production a room with good ventilation is required; a barricade, and an arrangement for remote control.

Accdg to Davis (Ref 23, p 405), E. Howard, after successfully prep MF in 1799-1800, attempted to prep fulminates of Au, Pt, Sb, Sn, Cu, Fe, Pb, Ni, Bi, Co, As, Ma & Ag, but only with Ag had any success. In 1802, L. Brugnatelli worked out a satisfactory method, which consisted in pouring onto 100 grains of powdered Ag nitrate, first an ounce of alcohol and then an ounce of nitric acid. After the ppt was formed, the slurry was immediately diluted with water (to prevent the dissoln of SF) and immediately filtered.

Because SF is extremely sensitive to friction and heat it quickly became an object of amateur interest and public wonderment; one of the standard exhibits of street fakirs, etc. J. von Liebig (1803-1873) saw, when he was a boy, a demonstration of SF in the market place at Darmstadt and learned how
to prepare it. He retained the interest in it and in 1823 conducted studies on SF in the laboratory of J.L. Gay-Lussac (1778–1850) in Paris (Ref 23, p 405).

Laboratory Procedure, as conducted at Picatinny Arsenal and described by S. Livingston was as follows:

1) To 1 g of pure silver powder, placed in a flask, was added a mixture of 8.5 g of nitric acid (d 1.42) & 1.2 g water preheated to 90–95° and this was left at RT until complete dissolution of silver.

Note: All these manipulations were conducted under the hood behind a safety screen.

2) The resulting soln of Ag in dilute nitric acid had temp of 60°. It was carefully added to a 150-ml balloon flask provided with a thermometer and contg 12.25 g of 95% ethanol (preferably not denatured).

3) The flask was then placed in a trough which could be filled with either cold or hot w. The temp in the flask was kept below 60°C by cooling the flask, if necessary. If the reaction started to slow down, the flask was slightly heated by adding some hot w to the trough. If some brown fumes started to appear in the flask, the reaction was slowed down by cooling the flask under cold w tap.

Note: As the fumes evolved during this operation are very toxic care was taken not to inhale them.

4) As the reaction proceeded, all of the SF precipitated in about 20 mins, giving practically 100% yield.

For the plant procedure, Livingston recommended using 10–15 g of silver and to increase the amounts of other ingredients correspondingly.

Note: Essentially the same laboratory procedure was described by Rinkenbach in Kirk & Othmer 8 (1965), p 590. Prepn of SF was also described by Taylor & Burton (See Addnl Ref C for SF). Prepn of sensitive form of SF was described by Taylor & Rinkenbach (See Addnl Ref D for SF).

Explosive Properties of SF. It is a more effective initiating agent than MF, although it has nearly the same brisance, judging by the Sand Test. It is more sensitive to heat than MF judging by its expln temp (170° vs 210° for MF in 5 secs). Its amorphous modification is (accdg to Rinkenbach) less sensitive to impact than its crystalline form. Since it is practically impossible not to have any crystals among the amorphous material, the whole mass might be as sensitive as if it consisted of crystals nearly exclusively.

In Table on p 412 of Davis are given the smallest amounts, in grams, of SF and MF required to detonate:

<table>
<thead>
<tr>
<th>Tetryl</th>
<th>PA</th>
<th>TNT</th>
<th>TNAns</th>
<th>TXN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>0.02</td>
<td>0.05</td>
<td>0.095</td>
<td>0.23</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.29</td>
<td>0.30</td>
<td>0.36</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Uses of SF. Extreme sensitivity, poor stability and high cost prevent the use of SF in commercial or military priming and detonating devices. It has been used however in small quantities in pyrotechnics and in devices used as toys. For example, Daniel (1902), p 318 described perorals, called "cosaques", used in France. In the US, Russia and other countries it has been used for prepn of "snaps", "pull-crackers", paper caps for toy pistols and "jumping frogs". Also in amusement devices such as "cigars" and "spiders". If a few grains of wet SF are spread on a floor, loud cracks are heard if they are walked upon (See Beil 1, 722 and Addnl Refs for SF).

Silver Fulminate (SF) and Telescope Mirrors. Telescope mirrors are silvered by prepn a soln of K hydroxide and Ag nitrate ammonia and covering the mirror with it. Unless the prepn steps are followed carefully, SF may form which is very expl. For this reason the USBuStd recommends that goggles be worn to avoid an unnecessary risk. The risk is especially great if the "silvering" soln is kept for more than several hours.

SF can expl while wet and it is so sensitive that it detonates by the mere movement of
the vessel contg silvering soln
E.H. Barry of NY told to Mr Cohn of Franklin Institute that, in order to test the stability of silvering soln it was allowed to stand over the weekend in closed room, in an open beaker. On Monday morning the contents and beaker fragments were found to have been scattered all over the ceiling. A similar accident was described in Scientific American, April 1932

It is recommended, in order to avoid accidents to the soln only as required and if any of it will be left over to keep it in tightly corked vessel, to avoid the possibility of lowering the level by evapn and the formation of a dried residue on the side walls. All the vessels used for keeping silvering soln should be carefully cleaned immediately after use.

Note: In some labs where BTF worked it was prohibited to pour into the sink any of the silver contg solns. A special bucket was provided for this and the soln was treated in order to recover silver

Sodium Fulminate, NaONC; mw 65.02, N 21.55%; wh crstls, sp gr 1.92, mp - explodes at 215° (in 5 sec→)(Ref 23, p 411); sol in w. Can be prepd by shaking Na amalgam with MF either in methanol or absol ethanol. Wöhler et al (Ref 10) prepd several explosive double salts and proposed using some of them in primers and detonators.

Davis (Ref 23, p 408) stated that Wöhler detd mol wt of NaF that corresponded to the single monomolecular formula of NaONC. This fact, taken together with the fact that MF warmed with concd q HCl yields hydroxylamine, NH₂OH, and formic acid proves that Fulminic Acid (qv) is the oxime of carbon monoxide:

\[
\text{HO-NC} \quad + \text{2H}_2\text{O} \rightarrow \text{HO-NH}_2\text{HCOOH}
\]

(See Refs 1, 6, 10, 18 & 23)

Sodium Cuprous Fulminate, Na[Ca(ONC)]₆, and Disodium-Cuprous Fulminates, Na₂[Ca(ONC)]₆.²H₂O; are solid complexes prepd by L. Wöhler et al and described in Ref 10. The first complex explodes violently by heat or impact. It was prepd by the action of cuprous chloride on NaF in w at 80°. The second complex expl violently on heating. It was prepd by the action of concd soln of MF on cuprous chloride in w at RT (pp 2754-56)

Thallium (Thallous) Fulminate, TlONC; mw 246.41, N 5.68%; colorless solid becoming yel on exposure to light; mp - expl at 120° in 5 secs. Can be prepd by shaking TI amalgam with MF in ethanol. It is an expl with very low heat of expln - 223cal/g, low gas vol, low briance, very low sensitiveness and low initiating efficiency. It takes 0.30g of TlF to initiate Tetryl and 0.43 for PA [See Ref 1, p 376; Ref 3, pp 1 & 18 and Ref 23, pp 411–12]

Refs for Fulminates, Including MF:

Addnl Refs for MF:
yields, 94–96%, were obtd with 1 p(by wt)
of Hg, 8.8p of nitric acid (61.5% strength),
8.8p of 96% ethanol, 8.8p of cp HCl & 1 p
delectric of Cu) V P.Y. Narayana,
CurrentSci 13, 313–15(1944) & CA 39, 4227
(1945) (Mercuric Parafulfminate or Parafalmine
W) Kasec-Metz(1944)(Prepn, props & analysis
of MF and of its mixtures) Wa L.R. Carl,
JFranklinst 240, 149–69(1945)(MF, its cata-
lytic reactions and their relation to detonation
X) All & En Exps(1946), 62–6(Props & uses of
MF); 156(MF may cause infection from con-
tact with skin cuts) Y) A.F. Belyaev &
A.E. Belyaeva, ZhFizKhim 20, 1381–89(1946)
(Combstn of MF) Z) A.R. Ubbelohde, Trans-
RoySoc A241, 286(1948)(Explanation why MF
is less sensitive to girt than LA. Heat of expln
of MF 410cal/g vs 364 for LA) AA E.
(1949)(Deaths of workers in contact with MF
primers was due almost exclusively to the
inhalation of vapors) BB) H. Henkin & R.
McGill, IEC 44, 1391–95(1952)(The lowest
expln temp 1750 was observed on prolated
heating in modified Marshall App. Heating for
5 secs at 208° produced expln) BBa) Gorst
(1957), 108(Gremuchaya Rutr)(MF)
CC) W. Brose, GerP 1016255(1957)(Prepn of
crystallized MF of the highest possible
bulk density) DD) R.S. Harris, ARDE GB
Memo (MX) 42/58(1958)(Production of MF of
improved thermal stability)(Conf – not used
as a source of info) EE) M.P. Murgai &
(Impact sensitivity of MF) FF) S. Nagayama
& V. Mizushima, KogyoKagakuKyokaishi 21,
290–96(1950) & CA 55, 24012(1961)(Crysts
of MF of different cryst habits were obtd by
varying the rate of crystn from solvents. They
differed in expln sensitivity and the crystns
from hot w were more sensitive because they
did not cont w of crystn)

Addl Refs for SF(Silver Fulfminate):
A) Mellor, "Comprehensive Treatise", Vol 3
(1923), p 381 B) Marshall 2(1917), 703
(Prepn & props) C) C.A. Taylor & E.P.
Buxton, ArmyOrdn 6, 118–19(1925)(Prepn &
props of SF) D) C.A. Taylor & Wm.H.
Rinkenbach, ArmyOrdn 6, 448(1926)(Prepn
of sensitive form of SF) E) Stettbacher
(1933), 328(Knallsilber) F) Sancho(1941),
193(Fulminato de plata) G) Davis(1943),
411–14(Prepn, props & uses of SF)
H) Pérez Ara(1945), 551–52(Fulminato de
plata) I) Vivas, Feigenspan & Ladreda,
Vol 2(1946), 315(Fulminato de plata)
J) Stettbacher(1948), 96(Knallsilber)
K) Belgrano(1952), 216(Fulminato di argento)
L) Stettbacher, Pölvorals(1952), 125(Fulminato
de plata) M) J.P. Springer, GetP 953415
(1956) & CA 53, 10765(1959)(Uses of SF in
pyrotechnic compds) N) Giua, Trattato 6
(1959), 418(Fulminato d’argento)
O) Lange(1961), 676–77(Props of SF)
590(SF) by Wm.H. Rinkenbach) Q) AMCP
706–177(1967) – not described R) TM
9–1300–214(1967) – not described

Mercuric Fulfminate and Its Mixtures, Quali-
tative and Quantitative Analyses and Speci-
fication Requirements and Tests
Specification Requirements of JAN-M-219:
1) Moisture
2) Preparation of Sample – Approx 70g of
the dry sample are needed to perform the
required determinations
3) Appearance – Crystals of sparkling ap-
pearance which are white, gray or light gray
with a yellowish tint
4) Mercury fulminate – 98.0% (min)
5) Acidity – None
6) Insoluble matter – 2.0 % (max)
7) Free mercury – 1.0% (max)
8) Chlorine – 0.05% (max)
9) Sand test – weight of sand crushed,
44g(min)
10) Granulation:
Retained on US Std Sieve No 100, %
(max) – 15
Thru US Std Sieve No 200, % (min) – 75
Laboratory Tests
112.1 Moisture
112.1.1 Desiccation Method. Dry to con-
stant weight in a desiccator containing calcium chloride, a known weight 0.4 to 0.7 g portion of mercury fulminate. Calculate the loss in weight as the percentage of moisture in the sample

112.1.2 Oven Method. Transfer an accurately weighed portion of approx 1 g of the sample to a tared glass moisture dish. Dry in an oven maintained at 55° to 65° for four hours or to constant weight. Calculate the loss of wt as % moisture.

112.2 Preparation of dry sample. Transfer two 35 g portions of the sample to two 2% inch glass funnels, each funnel having a filter paper folded and inserted in it. With the aid of suction, wash the Hg fulminate with enough 95% ethyl alcohol to remove most of the water. Place the filter paper holding the Hg fulminate in a small evaporating dish and dry in a sealed unit electric oven or steam oven at 40°C–50°C to constant weight.

112.3 Appearance. Determine by visual examination.

112.4 Mercury Fulminate. Transfer a weighed portion of 0.3 g of the dried sample to a 250 ml beaker. Add quickly 30 ml of a freshly prepared solution of sodium thiosulfate (20 g per 100 ml). Shake the mixture for exactly 1 minute. Titrate immediately with approx 0.10N HCl using three drops of methyl red indicator. It is important that titration begin exactly 1 minute after the addition of the sodium thiosulfate.

Add most of the HCl required immediately and complete the titration in not more than 1 minute. Make a blank determination with the same quantity of sodium thiosulfate solution. Calculate the percentage of Hg fulminate as follows:

$$\% \text{ Hg fulminate} = \frac{7.1116 (V - v) N}{W}$$

where: $V = $ ml HCl required for titration
$v = $ ml HCl required for blank
$N = $ normality of HCl used
$W = $ weight of sample

112.5 Acidity. Transfer a weighed portion of 10.0±0.1 g of the dried sample to a filtering crucible provided with a filter paper disc. Wash the sample with two 25-ml portions of boiled distilled water which has been cooled to RT. Add to the filtrate three drops of methyl orange or bromthymol blue indicator. Note if acid color appears.

112.6 Insoluble matter. Transfer to a 2-liter beaker a weighed portion of approx 1 g of the sample. Add 1 liter of distilled water at 90°C and stir while maintaining at a temperature of 90°C, until the material is dissolved. Filter the soln and transfer any insol material to a tared glass filter or crucible. Complete the soln and filtration within 1 hr. Prepare the filter or crucible by packing fine asbestos to a thickness of approx 0.2 inch on the sintered glass plate of medium porosity, washing with hot water, alcohol and ether while applying suction, and then weighing. Wash the insoluble material on the filter with hot water, alcohol & ether, and weigh. Calculate the increase in wt as % insoluble matter.

112.7 Free Mercury. To the insoluble matter, obtained as described in paragraph 112.6, add 2 ml of hot concentrated HCl, allowing this to remain for 1 minute prior to removal by suction. Subject the insoluble matter to this treatment three times, wash with hot water, alcohol & ether, and weigh. Repeat the procedure until the loss in weight is less than 0.0003 g. To the residue add three successive 2-ml portions of hot dilute nitric acid (1:1) in the same manner as with the HCl. Wash the residue with hot water, alcohol & ether, and weigh. Calculate the loss in wt as % of metallic mercury.

112.8 Chlorine. Transfer a weighed portion of approx 5 g of the dried sample to a filtering crucible equipped with a filter paper disc. Wash with two 25-ml portions of distilled water at 90°C–100°C, catching the filtrate in a test tube. Add to the filtrate three drops of nitric acid (sp gr 1.4) and 10 drops of a 10% soln of silver nitrate. Compare the turbidity with that produced when a soln of 0.0042 g of pure NaCl in 50 ml of distilled water is treated in the same manner. A greater turbidity indicates the presence of more than 0.05% chlorine in the sample.

112.9 Sand Test. Transfer to each of five empty No 6 blasting cap shells 0.400 g of trimethylamine (grade 1, US Army Specification 50–13–5) of such fineness that all of the material passes thru a 177 micron (No 80) US Std
sieve. Each blasting cap shall be composed of copper, gilding metal, or aluminum and shall be approx 1.46 inches long by 0.217 inch inside diam. With the cap held in a loading block, insert a plunger 0.20 inch in diam in the shell and subject the TNT to a pressure of 3000 psi (100 lbs actual load) for 3 mins. Remove the plunger and transfer to the shell 0.270g of Hg fulminate, insert a reinforcement cap (approx 0.217 inch outside diam, open at one end and a hole 0.11±0.03 inch diam at the other end) with the open end down. Insert the plunger in the shell and apply the pressure of 3000 psi for 3 mins. With a pin, prick the powder train in one end of a piece of miner's fuse 8 or 9 inches long. Crimp to the pricked end one of the caps loaded as directed above, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap to avoid squeezing the charge. Pour 80.0±0.1g of standard Ottawa sand which passes thru a 840 micron (No 20) US Std sieve and is retained on a 590-micron (No 30) US Std sieve, into the cavity of the sand test bomb. Level the sand by striking the bomb vigorously with a hammer at least five times while rotating the bomb on its axis. Lower the fuse and cap into the bomb cavity so that the cap is centered at the axis of the bomb and just touches the sand. Hold the cap and fuse in this position and carefully pour 120.0±0.1g more sand into the bomb, being careful not to disturb the position of the cap. To avoid possible error caused by the explosion blowing crushed sand thru the hole in the cover, slip a piece of rubber tubing, approx 1/8 inch long and of such inner diam that it fits the fuse snugly over the fuse and adjust at a point on the fuse so that the rubber will be against the inner side of the bomb cover with the loaded cap in position as described above. Carefully insert the fuse thru the hole in the bomb cover, lower the cover into position, and fasten securely. Strike the bomb vigorously with a hammer at least 5 times while rotating the bomb on its axis. Light the fuse, and after the explosion takes place, transfer the sand to a sheet of smooth glazed paper, taking care to remove any sand which may adhere to the sides of the bomb, or to pieces of the detonator shell, or burnt fuse. Empty all the sand on a 590 micron (No 30) US Std sieve fitted with a pan. Weigh the sand which passes thru the sieve after shaking 3 minutes, using a mechanical shaker.

112.10 Granulation

112.10.1 Wet Method. Transfer a dried and weighed portion of approx 10g of the sample to a 149-micron (No 100) US Std sieve which has been placed in a porcelain evaporating dish containing sufficient water to cover the wire portion of the sieve. Shake the sieve for 10 mins in such a manner that the Hg fulminate is below the surface of the water and any material passing thru the sieve is caught on the evaporating dish. Transfer the portion of the fulminate retained on the sieve to a tared filter paper and wash twice with alcohol and once with ether. Dry the filter paper and fulminate at 50°C for 1 hr, cool in a desicator, and weigh. Calculate the increase in wt as % retained on the No 100 sieve. Transfer the portion of the sample caught in the evaporating dish to a 74-micron (No 200) US Std sieve and sift as described above. Transfer the material caught in the evaporating dish to a tared filter paper, wash, dry and weigh as before. Calculate the increase in wt of the tared filter paper as % passing thru the No 200 sieve.

112.10.2 Dry Method. When Hg fulminate is sifted dry, the operation shall be performed in a location safely removed and/or shielded from other explosives, personnel or material which should be harmed by explosions. The motor of the shaking machine shall be started and stopped by a remote control switch. Assemble a No 100 sieve on a No 200 sieve and fit them on a pan. The sieves must be fitted with rubber gaskets. Place a 5g sample of dry fulminate on the upper sieve and shake the sieve for 3 mins on a Tyler Ro-Tap (or equal) machine. Carefully brush the material retained on the upper sieve into a weighing pan and weigh. Calculate the wt as % retained on the No 100 sieve. Brush the material passing thru the No 200 sieve from the pan, weigh & calculate as % passing a No 200 sieve.

Methods of detection and determination of MF are listed in Refs which follow.
The following mixes contg MF used in fuzes are described in Vol 4 of Encycl: p D1060-R. Primer Mix, New No 4 – formerly used in rifle grenade fuzes and covered by the US Military Spec MIL-P-2499 (1950). The Spec is now cancelled p D1063-R. Primer Mix for M3 Igniter Cartridge used in 8mm Mornar Ammunition contains MF, Sb$_2$S$_3$, ground glass, KClO$_3$ and water-soluble binder. Its requirements and tests are covered by US Military Spec MIL-C-20480A (1954)

Comps of some US Priming Mixes contg MF and used in fuzes are given in TM 9-1300-214 (1967), p 7-17, entitled “Military Explosives”

### Priming Comps Contg MF

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>K chloride</td>
<td>45</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>Sb sulfide</td>
<td>23</td>
<td>30</td>
<td>21</td>
</tr>
<tr>
<td>MF</td>
<td>32</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Ground glass</td>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>Shellac</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

I is loaded dry but can be wet loaded w alc
II is loaded dry
III is prepd with shellac dissolved in alc and wet loaded

**Refs for Analysis of MF and Its Mixtures:**

1) H.W. Brownson, JSCI 24, 381–82 (1905) (Quantitative det of MF); also described and reviewed by R. Philip, SS 7, 109ff (1912)
2) A. Solonina, SS 5, 41–6 (1910) (Det of MF)
3) Marshall 2 (1917), 701–02 (Estimation of MF, including Bofors Method)
4) G.S. Heaven, JSCI 37, 143T (1918) (Analysis of MF)
5) A. Langhan, ZAngewChem 31 (1), 161–3 (1918) & JSCI 37, 637A (1918) (Colorimetric det of MF with Phenylhydrazine)
6) P. Nicolardot & J. Boudet, CR 166, 288–89 (1918) (Analysis of MF)
7) H. Rathburn, Ber 54B, 3185 (1921) (Analysis of MF)
8) A. Langhans, ZAnalChem 60, 93–4 (1921) (Detection of MF)
9) A. Langhans, SS 17, 122ff (1922) & 18, 6ff (1923)
10) C.A. Taylor & W.H. Rinckenbacht, “Explosives”, USBurMines Bull 219 (1923), pp 62–3 (Analysis of MF); 162 (Analysis of fulminate–chlorate–Tetryl detonating mixes); 163 (Analysis of fulminate–chlorate–TNT detonating mixes); 163 (Analysis of fulminate–chlorate–NMan–NC detong mixes); 164 (Analysis of MF–NC initiator); 164 (Analysis of a loose MF–chlorate initiator); 167–68 (Analysis of primer mixts of MF, chlorate and antimony sulfide); 168 (Analysis of primer mixt: MF, K chlorate, antimony sulfide & glass); 171 (Analysis of primer mixt: MF, Pb Picrate, Sb sulfide, Ba nitrate & Ba carbonate); 172 (Analysis of primer mixt: MF, Sb sulfide, Ba nitrate, Picric Acid and glass)
11) Clift & Fedoroff, Vol 2 (1943), pp F4 & F5 (Bofors Method of Estimation of MF content); p F5 (Color reaction of MF with Phenylhydrazine)
11a) Kaste-Metz (1944) (Testing of MF)
12) Belgrano (1952), 213–6 (Analysis of MF and its mixts)
14) H.C. Sayce, ERDE GB Report No 33/R/59, Jan 1960 (Analysis of MF and its application to Fulminate in storage) (Conf – not used)
16) A.R. Lusardi, “Laboratory Manual”, FREL Picatinny Arsenal, Sections 100 & 200 (1962), Method 112 (MF, applicable Spec JAN-M-219); Method 203 (Analysis of Primer Mix New No 4, which contains MF, K chlorate & Sb sulfide; applicable Spec MIL-P-2499)
18) StdMethodsChemAnalysis, Vol 2, PT B (1963), Chap 32 by R.H. Pierson; p 1346 (Detection of MF); p 1366 (Analysis of comp contg MF & K chlorate)
20) US Military Specification JAN-N-219 (1945) (Mercury Fulminate)
21) US Military Specification MIL-P-2499 (Oct 1950) (Analysis of Primer Mix New No 4, contg MF, K chlorate & Sb sulfide)

**Fulminating.** An old Dynamite proposed by Mr Fuchs of Upper Berat, Silesia. It consisted of NG–68% or more adsorbed on “laine tontisse” (sheared wool)

**Refs:**
1) Daniel (1902), 349
2) Gody (1907), 359
Fulminating. An older expression meaning capable of causing explosion or detonation. It is derived from Latin fulmen, which means lightning flash or thunderbolt
Ref/s: 1) Davis (1943), p 400 2) Hackh’s Dict (1944), p 359-R

Fulminating Compounds. Fulminating gold, mercury, silver and platinum are formed by precipitating sols of these metals with ammonia. They are perhaps nitrides or hydrated nitrides, or perhaps they contain hydrogen as well as nitrogen and water of composition, but they contain no carbon and should not be confused with fulminates which are salts of Fulminic Acid, HONC. They are dangerously sensitive, and not suited for practical use

Their discovery is described under individual compounds
Ref/s: 1) Davis (1943), 400 2) Clift & Fedoroff 2(1943), p F6

Fulminating Gold (FG) (L’or fulminant in Fr, Aurum fulminans in Latin, Knallgold in Ger, Oro fulminante in Ital or Span, Gremucheye zoloto, in Russ). This compound and other fulminating compounds must not be confused with fulminates, described above. Some scientists, accdg to Daniel (Ref 1, 314) consider them identical with nitrides (azotures, in Fr)

Accdg to Davis (Ref 4, p 400), FG was discovered by Basil Valentin (German monk and alchemist living in the 15th century), but the first known description of this discovery is given in writings of Johann Thölede (or Tholden), published in 1602–1604. The compound was called Goldkalk and was prep’d by dissolving gold in aqua regia (which was made by dissolving sal ammoniac, NH₄Cl, in concd nitric acid) and then adding K carbonate soln. The resulting powdery ppt was washed by decantation 8–10 times, drained from water and then dried in the air where no sunlight fell on it and not near any fire. The compound was very sensitive to heat and could explode with great violence. The author also reported that warm vinegar converted the expl compound to an inexpressible material

The name aurum fulminans was given by Beguinus, who described in 1608 its prepn (Ref 4, p 401)

Daniel (Ref 1) stated that l’or fulminant deposits as a chamois (clear yel) powder on treating gold trichloride with ammonia. The same method is listed by Davis on p 401, who also says that the method of prepn by Basil Valentin succeeded because the sal ammoniac used for the prepn of the aqua regia supplied the necessary ammonia. If gold is dissolved in aqua regia prep’d from nitric acid and common salt, and if the soln is treated with K carbonate, the resulting ppt is not expl. FG loses its expl props if it is allowed to stand in contact with sulfur

Strettbacher (Ref 3) stated that Aurum fulminans can be prep’d by treating auric oxide, Au₂O₃ (freshly ppt’d by treating the soln of auric chloride with an alkali and filtering) with ammonium hydroxide in the manner similar to prepn of Fulminating Silver (qv). It forms olive-green to yel-bm powder which in dry state detonates with sharp sound on being touched

Accdg to Strettbacher, the constitution of FG was not defined, but accdg to Pérez Ara (Ref 4, p 567), the formula of oro fulminante is Au(N₃)₃ and that it is nitrato aurico (Gold Nitride in Engl). This formula, however, seems to be identical with an azide

Strettbacher, quoting the work of Langhans (Ref 2), stated that Aurum fulminans is the most ancient brisant explosive known and that manipulation with it in the past caused many serious accidents. For example, the famous Swedish chemist Baron J.J. Berzelius (1779–1848) lost both eyes while working with FG (Ref 2, p 330)

Accdg to Davis (Ref 4, p 401) and Pérez Ara (Ref 4, p 567), Cornelius Drebbel, the Dutch inventor and chemist of the 17th century, while being in the service of British Navy, devoted considerable time to the prepn of FG and used his material as a detonator in petards and torpedoes used in the English expedition of 1628 against the French port of La Rochelle

Accdg to the diary of Pepys of Nov 11, 1663 (quoting from Ref 4, p 401), FG is so powerful and brisant that if one grain of it is
exploded on a surface of a silver spoon, a
blow like a musket was heard and this punched
a hole thru the spoon

FG is not suitable for practical use on
acct of its extreme sensitiveness to shock,
friction or heat, and also to its high cost (Ref
5, p 568
(Compare this compd with Auric Imidoamide or
Gold Amidoimide, described in Encycl under
AMIDES, IMIDES AND DERIVATIVES on p
A169-L of Vol 1. It seems that the compd
there was erroneously named Fulminating Gold)
Refs: 1) Daniel (1902), 313-14 2) A. Lang-
hans, SS 25, Sonderdruck 70 (1930)(Explosionen,
die man nich erwarten) 3) Slettheiner (1933),
330-31 4) Davis (1943), 400-01 5) Pérez
Ara (1945), 567-68

Fulminating Mercury or Mercury Nitride.
Acddg to Marshall (Ref 1), its formula is
Hg₃N₂, mw 629.85, N 4.45% and it can be prep'd
by treating mercury oxide with ammonia. It is
very sensitive and must not be confused with
Mercury Fulminate

Acddg to Davis (Ref 2), Fourcroy, by di-
gesting red oxide of mercury (HgO) in ammonia
water for 8 to 10 days, prep'd a material which
became white and finally assumed the form of
crystalline scales. The dried product exploded
loudly from fire, but underwent spontaneous de-
comp when left alone. At slightly elevated
temp it gave off ammonia and left a residue of
mercury oxide

In the Journal de Physique for 1779 the
French apothecary Bayen described a fulmi-
nating mercurial compd of a different kind. It was
obtd by mixing 30 parts of precipitated Hg
oxide(washed and dried) with 4 or 5 parts of
sulfur. This mixt exploded violently when
struck with a heavy hammer or on being heated
on an iron plate

Acddg to Pérez Ara (Ref 3), there exist
two nitrosos de mercurio (Mercury Nitriles) –
one is mercurous, while another is mercuric

None of the above listed expls found ap-
lication in commercial or military primary or
detonating compns, but they are interesting
from an historical point of view

Refs: 1) Marshall 2(1917), 703  2) Davis
(1943), 402  3) Pérez Ara (1945), 567

Fulminating Platinum (FP) (Platine fulminant
in Fr)

Acddg to Daniel (Ref 1), when a soln of
platinic oxide in sulfuric acid was treated with
an excess of am ammonia; a black ppt of pla-
tiine fulminant was obtd. When dry it detonated
violently by shock, friction and heat (at 160°).
Some scientists consider it as being identical
with the nitride (azoture, in Fr)

Acddg to Davis (Ref 4, p 402), FP was first
prep'd by Davy (Sir Humphry, 1778 to 1829) about
1825, by adding ammonia water to a soln of Pt
sulfate, boiling the ppt with a soln of porash,
washing, and allowing to dry. It was exploded
by heat, but not easily by percussion or fric-
tion. No formula is given

Acddg to Jacobson (Refs 2 & 3), the compd
of the formula (HO)₅PtNH₃Pt(OH)₅ was prep'd
by him by treating dichloroplatinum acid with
an excess of ammonia. The soln first turned
dark and then a brownish ppt appeared, which
could be separated and dried. When heated, it
blackened and detonated violently yielding Pt,
N₂, O₂ and H₂O vapor. Dichloroplatinum acid
was obtd in 80-90% yield by boiling Ag tetra-
chloroplatinate in water

A compd of similar props,
(HO)₅PtC₅H₅NPt(OH)₅, was obtd by the action
of pyridine on dichloroplatinum acid
Refs: 1) Daniel (1902), 313 & 314(Platine ful-
miant)  2) J. Jacobson, CR 149, 574-77
(1909) & CA 4, 1002(1910)  3) Clift &
Fedoroff 2(1943), p F6  4) Davis (1943), 402

Fulminating Powder of Forsyth. Under this
name Newman (Ref) lists the mixture of K
chlorate, sulfur & charcoal which could be
detonated by percussion. It was invented at
the beginning of the 19th century by the Scotch
clergyman, A. Forsyth. It was replaced later
by the mixture consisting of K chlorate, MF &
powdered glass
Ref: J.R. Newman, "Tools of War", Double-
day-Doran & Co, NY (1943), p 42
Fulminating Powders Described by Davis.  
One of the fulminating powders was made, accdg to Ure's "Dictionary of Chemistry", Philadelphia, Pa, 1821, by triturating in a warm mortar 3 parts by wt of nitre, two of carbonate of potash and one of flower of sulfur. Its effects, when fused in a ladle and then set on fire, were very great. The whole of the melted material exploded with an intolerable noise, and the ladle disfigured, as if it had received a strong blow downwards. It was three times quicker than common BkPdr.

A similar powder was manufd by S. Guthrie, Jr and sold in 1930's in this country. He proposed, however, another powder, which he claimed to be superior to the above mixture. For its prep, were melted together 2 pts of nitre with 1 pt of K carbonate and, when the mass cooled, adding to 4½ ps of it 1 pt of sulfur. This pdr was claimed to be no less than 8½ times quicker than the best common BkPdr. More details are in Ref. Ref: Davis (1943), 31.

Fulminating Powders, History. It seems that the earliest discovery dates to the 15th century, when Fulminating Gold (qv) was prep'd by Basil Valentin. Discoverers of other fulminating compds are listed under individual compds.

A résumé of description given in the book of Greener (Ref) is given below:

Accdg to him the first researchs on fulminating powders were made in France by Peter Bolduc prior to 1700 and also by Nicolas Lemery prior to 1712. Nothing of importance appears to come out of their researchs, but the work was continued in that direction until 1774 when Bayen (Chief Army Physician to Louis XV) prep'd MF and made known its explos props. No use of it was made at that time, due probably to its extreme sensitiveness. The work on fulminating expls was continued by Fourcroy, Vauquelin and Berthollet (qv). The last scientist discovered K chlorate and proposed using it in lieu of K or Na nitrates in BkPdr. The resulting Berthollet Powder (qv) was too dangerous to handle (See Vol 2 of Encycl, p B107-L). Then Berthollet turned his attention to fulminate and succeeded in preparing Silver Fulminate (qv) and used it for pyrotechnic displays. Attempts to use it as a primer in firearms were unsuccessful due to its even greater sensitiveness than that of MF. Fourcroy & Vauquelin attempted to diminish the sensitiveness of SF by combining it with combustible ingredients, such as sulfur, but it does not seem that they succeeded. Same investigators tried other fulminating mixts, such as Ag chlorate with sulfur; K iodate with Ag powder and Au, K or Ag Ammoniates (See AMMINE or AMMONIATE in Vol 1 of Encycl, pp A275ff).

In 1800 E. Howard, an Englishman, after a study of works of French chemists, prep'd a mixture consisting of MF and salt peter. This mixt, known as Howard's Powder was suitable for use in primers.

None of the above-mentioned scientists (including Howard) patented his inventions and for this reason the invention of fulminating mixture is generally attributed to the Scotch Clergyman, A.J. Forsyth, who took in 1809 a patent relating to the application of the detonating principle for exploding BkPdr in firearms. (See also "Fulminating Powder of Forsyth")

A short time afterwards (1808), a Swiss gunmaker, Pauly, working in Paris, invented a percussion breech-loading gun in which a fulminating paper cap was affixed to the cartridge in the breech. Upon pulling the trigger a needle pierced the cap which ignited the charge of fulminating mixture. Although this invention was soon abandoned, Germans used the same idea when they patented in 1836 their needle gun.

In 1812, Pauly invented another percussion device. Here, a small piston, actuated by a spiral spring, struck a nipple upon which a few grains of MF were placed.

In 1818, the copper percussion caps were made in England, simultaneously by several gunsmiths, among them Joe Manton. Col Hawker claimed that he improved the Manton cap. In France, the copper cap was introduced by Degoubert in 1819.

Among other English inventors of percussion devices may be mentioned Egg, Wilkinson, Lancaster, Long and Westley-Richards.
Notwithstanding the advantages of percussion devices over the /lintlock/(qv), they were not adopted until 1840 by the English and French.


**Fulminating Silver of Berthollet.** (L'argent fulminant de Berthollet in Fr; Berthollet'schen Knallisilber in Ger). This compound, of indefinite formula, was first prepared in 1667 by Baron Johann Kunckel von Lœwenstern (See under Mercury Fulminate) and then, more than one hundred years later, by Berthollet (Ref 1). Other chemists, such as Gay-Lussac, Faraday, Proust, Higgins, Raschig, Matignon etc., were interested in the compd and many accidental expls occurred during its prep and investigation (Ref 4a).

Berthollet (Refs 1 & 7) prepd FS in 1788 by adding lime water to a soln of Ag nitrate, separating the resulting ppt of Ag oxide, drying it and treating with strong Amm hydroxide. The resulting black solid was washed by decantation and dried on filter in open air. It could also be prepd by adding ammonia to very small quantities of the aq soln of Ag nitrate until the ppt, formed at first, is redissolved; NaOH was then added which pptd a black "fulminating silver". It was a very violent expl of indefinite compn (Ref 5). Several formuls were ascribed to this compound, such as AgNH₂, Ag₂NH, Ag₂N₂, Ag₃N, AgO₂NH₃ etc., but according to the investigation of Baum (Ref 4), its formula is Ag₂O.NH₃.

Accdg to Davis (Ref 7, pp 401–02), FS is more sensitive to shock and friction than FG, being exploded when touched. It must not be enclosed in a bottle or transferred from place to place, but must be left in the reaction vssel, or better upon paper, where it is allowed to dry.

*Note:* The black material which deposits in a reagent bottle of ammoniacal Ag and sometimes collecting on the rim & around the stopper contains FS. Expls have been reported being caused by careless turning of the glass stopper of a bottle contg this reagent. After a test (for aldehyde, for example) has been made with ammoniacal Ag nitrate soln, the liquid should promptly be washed down the sink and all insol matter left in the reaction vssel should be dissolved with nitric acid.

It is too sensitive to be used for any practical purpose (See also Silver Amide, under Amides, Inorganic in Vol I of Encycl., p A169-R).


**Fulminating (Ger).** Mixture of NG 85 & wool shearrings (clippings) 15% proposed by Fuchs of Alt Berau, Silesia.

*Ref*s: 1) Daniel (1902), 319 2) Gody (1907), 359 3) PATR 2510 (1958), p Ger 53-L

**Fulminic Acid** or **Paracyonic Acid** (Oxime of Carbon Monoxide) (Knallsiure in Ger; Acide fulminique in Fr; Gremuchaya Kislot in Russ).

HONC.C=NOH.C=NOH=NO.H. Other methods of prepn are boiling an aqueous soln (with or w/o mineral acid) of methyl nitric acid, O₃N.CH=NOH, and then adding a metal salt to precipitate the fulminate (Ref 3) or acidifying aminemethylnitric acid, O₃N.C(NH₂)=NOH, aminiformoxime, H₂N.CH=NOH (Ref 4). Davis
Silver salt, Ag'F', ndls; sol in hot w (Ref 2)

Fulmison. A Dynamite containing nitratred bran with 30-40% of NG
Ref: Daniel (1902), 320

Fulmitriguanurate, C₆H₁₄N₉O₆; mw 257.22,
N 49.01%; wh ndls, sol in warm w. Structure not known. Prepd by heating Mercury Fulminate with ammonia at 70°. Completely decomposed to CO₂ and NH₃ by dil HCl at 150°. Neutral in water, but will react with metal oxides giving, eg, a Silver salt, Ag₂C₆H₉N₉O₆
Refs: 1) Beil 1, 723 2) A. Steiner, Ber 8, 522 (1875) 3) Ibid, 9, 784 (1876)

Fulph & Lockovic Explosive (Hungarian):
Fresh horse dung 60, K nitrate 26, sulfur 10 & dye 4%.
Note: Accdg to Daniel (Ref 1), fresh horse dung contains ammonical salts, which can form an explosive when mixed with other ingredients.
Refs: 1) Daniel (1902), 320 2) Fedoroff & Clift 4 (1946), 37

Fumaric Acid and Derivatives
Fumaric Acid or Butanedionio Acid,
HOO.C.H.CH.CO.H; mw 116.07, colorless prisms, mp 286-87° (in sealed tube), bp 290°; sl sol in w & in eth; sol in alc. Can be prepd by fermentation of molasses; isomerization of maleic acid or catalytic oxidation of benz. Used for prepn of polyester resins, molding powders and for many other purposes indicated in Ref 2.

Fumaric Acid Dioxide or Fumaryl Azide,
(N₉)OC.CH.CH.CO(N₉); mw 166.10, N 50.60%, OB to CO₂ -67.5%; fine crystals, explodes vio-

Fulminpaille or Paléine. Dynamite invented by Langfrey in 1878, which contained: Fulminpaille (Nitrostraw) 18.6, NG 35.0, salt peter 32.5, flowers of sulfur 4.6 & starch 9.3%. The last two ingredients can be replaced by charcoal and by dextrine.
Ref: Daniel, Dict (1902), 319 & 596

Fulmin Acid (Nitromalcombre-amid-nitril in Ger) and Fulminrates, NCH(NO₂)CONH₂;
mw 129.08, N 32.56%, OB -55.8%; prisms (alc), mp 145° (dec); sol in w & alc. Is tautomeric with NCH(=NOH)CONH₂. Obt by spontaneous dec of O₂NCH(CH=NOH)₂ in water (Ref 3); by treating with concd ammonia NCH(N=O)CO₂Et (Ref 4); by refluxing Mercury Fulminate with 2N NH₄Cl (Ref 2); to obtn the free acid from its alkali salts, convert to the Ag salt with AgNO₃ and treat with HCl or H₂SO₄ convert to the basic Pb salt with basic Pb acetate and treat with H₂SO₄.
Following are its salts:
Ammonium salt, NH₄("F"'), prisms; sol in hot w (Ref 2)
Copper salt, Cu("F")₄.4H₂O, rh green crysts (Ref 1)
Copper salt, Cu("F")₄.4NH₄, dk bl prisms, expl over 150°. Prepd by refluxing fulminuric acid with ammoniacal copper soln (Ref 1)
Mercury salt, Hg("F")₂, crys powd. Prepd from fulminuric acid and Hg(NO₂)₂; also a monohydrate prepd using HgO (Ref 1)
Potassium salt, K("F"'), prisms; sol in cold w, dec over 225° with expl at higher temp (Ref 2)
lently at 45° even when heated slowly; very sensitive to impact while wet; can be prepared by introducing NaN₃ in water to an aq soln of fumaric hydrazide acidified with acetic acid. The product is too sensitive for practical use


**Fumaric Acid, Nitrated Derivatives**, not found in Beil or in CA thru 1966

**Fumaric Acid Peroxide or Fumaryl Peroxide** (Polymers), \(\left[\text{OC.CH(CH\_CO}_\text{O}\right]_x\text{, mw 114.06},\text{, O 56.11%; wh, very unstable powder; mp } 80^\circ\text{; insol in w & alc. Can be prepared by treating fumaric acid dichloride with Na peroxide in ice water. Exploses on heating or when brought in contact with aniline or alcoholic ammonia}

*Refs: 1) Beil 2, 743 & [630] 2) L. Vanino & A. Thiele, Ber 29, 1726 (1896) 3) F. Fichter & A. Fritsch, Helv 6, 333 (1923) and JCS 124, 1, 428 (1923) (Decomposition by heat)***

**Fume Characteristics.** In commercial blasting, one needs to know what poisonous gases & condensed products may be produced and in what proportions they may be found in the atmosphere following a blast. The poisonous gases are referred to in the expl industry as fumes. Limitations of the various methods used to measure fumes (Bichel gauge, Crawshaw gage & Trauzl block) have been recognized for years. The USBu Mines classification of permissible into Class A & Class B is based on a closed-bomb method.

Many studies more nearly representative of field conditions have been carried out by various investigators. One important finding was the observation of appreciable undetected expl or expl ingredients in the products of deton. Nitrostarch expls have fume characteristics somewhat better than comparable grades of NG Dynamites, but they do not possess many other desirable props of dynamites

*Ref: Cook (1958), pp 15 & 283*

**Fumée.** Fr for smoke

**Fumée, Poudres sans.** Fr for Smokeless Propellants

**Fumelessite.** A smokeless propellant invented by Boyd of Birmingham in 1896. Its compn was similar to that listed under Boyd Powders in *Vol 2* of Encycl, p B259-L

**Fume-Off.** The oxidative destruction of by-products in nitration reactions


**Fume Recovery at US Plants Manufacturing Nitrocellulose.** Manuf of NC is described in *Vol 2* of Encycl, p C102-R, under CELLULOSE and in *Vol 3*, pp C536 to C539, under CORDITE. However, no "Fume Recovery" was described although we had in our possession sketches with brief descriptions of fume recovery methods as practiced during WWII at Radford Ordnance Works, Virginia, operated by the Hercules Powder Works, and at Indiana Ordnance Works, Charlestown, operated by the DuPont & Co.

For addl info, see

*Ref: 1) W. de Svesnikoff, USP 1406353 (1922) & CA 16, 1321 (1922)***

**Fume Tests** *(Nitrocellulose Stability Tests)*

Several NC stability tests are based on the direct observation of the appearance of brown fumes produced on heating NC.

*Simon Thomas Fume Test* is one of the oldest (1898) of its kind and was conducted by heating an expl in a loosely stoppered flask to 100° for eight hours each day until
the appearance of brown fumes (Refs 1, 10 & 11). The same test was used in Holland in a slightly modified form (Ref 5), as follows:

A 2.5g sample of air-dried NC was placed in a 30ml flask and heated, unstoppered, for four hours at 95°.

The flask was left until the next day, then it was stoppered and heated for 8½ hours.

This was repeated for as many days as required to produce brown fumes, distinctly visible when the flask was held against a white background.

Generally, NC of 11.0–11.5% N required about 24 days; 11.5–12.0% – 23 days; 12.0–12.5% – 21–22 days; 12.5–13.0% – 15–20 days and 13.0–13.4% – about 14.5 days.

American Test at 65.5° also called 65.5°C Surveillance Test. This test was designed at the US Naval Powder Factory (now called the Naval Propellant Plant) by G.W. Patterson (Refs 2, 12 & 13) for testing the stability of smokeless propellants has been conducted at Picatinny Arsenal as follows:

For this test use a clean, dry 8-oz, colorless, special resistance glass, wide-mouthed bottle with velvet ground mushroom stopper which provides an air-tight seal. The bottle must be etched or ground on the side (1x2 inches) so as to be suitable for labeling. The alkalinity of glass must be not more than 0.02%, calcd as KOH. To determine the alkalinity, place 10g of ground glass in a Pyrex flask, add 20ml of N/20 HCl soln, allow to stand for 24 hrs and titrate with N/20 KOH, using phpttr indicator.

1) Transfer a 45g sample of propellant to the above bottle. If the propiant is for a 10-inch or larger cannon, use a test sample of 5 proplnt grains, or as many as can be inserted in the bottle.

Note: For small diam rocket propiant sticks, cut a sufficient number of 3-inch lengths. For large diam sticks (up to and including 1½ inches) cut a sufficient number from the length. For cylindrical sticks larger than 1½ inches in diam, cut a longitudinal section thru the center, 1 inch wide on the grain surface, 1½ inches in depth, and of sufficient length. For larger cruciform sticks, cut a longitudinal section from one arm, ¾ inch wide on the exterior grain surface and ¾ inch deep on the recession, and of sufficient length. Include lateral inhibitor, if present. For sphere propoints, cut sufficient lengths 2½ inches wide, and coil

2) Stopper the bottle by simultaneously twisting and pressing on the stopper. Label the bottle so as to show the lot number of the proplnt and the date on which the test is begun.

3) Place the bottle with contents in a chamber maintained at 65.5±1°C (See Fig on p 28 of Ref 12 and on p 49 of Ref 13), the aim in which is preferably maintained in constant circulation. After the bottle with contents has been heated for 24 hrs, reseat the stopper. Make daily observation of the appearance of the sample and note the number of days required to cause the liberation of visible reddish or brownish fumes of oxides of nitrogen.

Note: It has been customary to consider any propiant having a test value of 90 days or less to be of definitely impaired stability and any propiant having a test value of 20 days or less to be sufficiently unstable as to require destruction or salvage.

80°C Surveillance Test is conducted in the same manner as the 65.5° test, except that the temp of the chamber is maintained at 80°C±1°C. This test is made along with the 65.5° test in order to obtain more rapid (anticipatory) data.

78°C Surveillance or Hot Storage Test. Accdg to Wiggam & Goodyear (Ref 9), the 65.5° test is too time consuming and they recommend conduct the test at 78°.

75°C International Test. This test, which is a slightly modified procedure of Lenze & Pleus (Ref 4) can be used for HE's and pyro mixts. The following description is given in Ref 12, p 13 and in Ref 13, p 18:

Transfer a 10g portion of the sample as received to a weighing bottle 35mm in diam and 50mm high, cover with a watch glass, and weigh on an analytical balance. Heat the covered bottle with contents at 75° for 48 hrs, cool in a desiccator and weigh. Calc the loss in wt to percent and report as volatility of sample
Note whether the material has undergone decomp or is markedly volatile, as indicated by 1) Discoloration 2) Appearance of colored fumes above the sample 3) Development of an odor indicating acidity and 4) Loss of wt distinctly in excess of moisture content (as previously detd by a method appropriate to the material)

100° German Fume Test (Lagerung bei 100°). A 10g sample is weighed into a special glass-stoppered bottle and heated at 100°. The bottle is opened every 24 hours for 10 minutes to admit some air, and the heating continued until the appearance of brownish-red fumes

A powder is considered stable if it takes about 10 days to develop fumes; 3–5 days -- not as good and below this, bad or very bad (Ref 6, pp 382–83)

75° German Fume Test (Warmlagermethode 75°). This test is suitable for Nitrocellulose and propellants:
1) Several 5g samples of expls are heated at 75° in glass-stoppered tubes, 28mm in diam and 200mm in length
2) The tubes are left open for 16 hrs and then heating is continued (with stoppers tightly closed) without interruption until distinct reddish-brown fumes appear
3) If the fumes do not appear in one week, the tube is opened for 10 minutes, to renew the supply of oxygen necessary to convert NO to NO₂ and the heating continued

This test was later improved by von Meerscheidt-Hüllessem (Ref 8) and was claimed to give very reliable results

The propellant was considered very stable if it took not less than 130–150 days to develop reddish-brown fumes, stable -- not less than 70–120 days; passable — not less than 50–60 days; unstable — at 10–40 days and very bad at less than 10 days. The latter propellant had to be destroyed

Refs: 1) S. Thomas, ZAngewChem 2, 1027 (1898) and 20, 1143 (1907) 2) G.W. Patterson, SS 5, 47 (1910) 3) 8th IntemlCongrApplied-Chem (1912), Appendix, Sectn 3(b), p 311 4. F. Lenze & B. Pleus, SS 14, 311–17 (1919) 5) G. de Buijn, Rec 40, 642 (1921) and SS 17, 59 (1922) 6) F. Lenze & L. Metz, SS 23, 382–83 (1928) 7) A. Stettbacher, SS 24, 172 (1929) 8) F. von Meerscheidt-Hüllessem, SS 25, 141 (1930) 9) D.R. Wiggam & E.S. Goodyear, IEC (Anal Ed) 4, 73–6 (1932) 10) Reilly (1938), 80–1 11) Clift & Fedoroff 2 (1943), p N22 (Thomas Test) 12) A.J. Clear, PATR 1401 (Rev 1), 13 & 28 (1950) 13) A.J. Clear, PATR 3278 (1965), pp 22–3 & 49 (65,5°C and 80°C Surveillance Tests) 14) Fordham (1966), 78–9 (Fume Test by firing a round in a part of a mine which can be completely cut off from the circulating air, followed by taking samples of resulting atm for analysis. Another method consists of firing the expl sample of known wt in a steel vessel reinforced with concrete, followed by removal of resulting gas for analysis. The common procedure to det N peroxide after a period sufficient to allow oxidation of N oxide. The Griess Ilosvay method is recommended; carbon monoxide can be estimated by reaction with iodine pentoxide)

Fumigène. Fr for a pyrotechnic smoke mixture. One of the pre-WWII French mixtures contd tetrachloroethane 40, ZnO 20, powdered Zn 15, Ca silicide 15 & Na chloride 10%

Ref: Pepin Lehalleur (1935), 470

Fumigène, Compositions (Fr). The following compositions fumigènes (smoke comps) were patented in France in 1954 by Reure and published in 1956 by MP (See Ref)
### Table

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Composition I %</th>
<th>Composition Ib</th>
<th>Composition II</th>
<th>Composition III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl chloride</td>
<td>21.4</td>
<td>21</td>
<td>25</td>
<td>24.4</td>
</tr>
</tbody>
</table>
| Diethylpenta-
  chloride          | 16.5            | 17             | 16             | 15.2            |
| Diethyl-
  phthalate         | 3.6             | -              | 2              | -               |
| K chlorate                  | 34.8            | 36             | 27             | -               |
| Amm chloride                 | -               | -              | -              | 27.5            |
| Zinc                         | 21.4            | 22             | 22             | 27.4            |
| Trichlorobenzene             | 1.7             | -              | -              | -               |
| Dibutyl-
  phthalate        | -               | 4              | -              | 2.1             |
| Hexachloro-
  ethane            | -               | -              | -              | 3.6             |
| **Total**                   | **99.8**        | **100**        | **90**         | **100.1**       |

*Ref:* Gemain Reure, FrP 1078608 (1954) & MP 38, 419–21 (1956)

### Fuming Nitric Acids

There are WFNA (white fuming nitric acid) and RFNA (red fuming nitric acid). They are described under Nitric Acid and in CondChemDict (1961), p 800-R; (1971), 618-R

### Fumyl

A fine, buff-colored mixture used by the Russians during WWI as a smoke producing compo inside shrapnel shells. It consisted of TNT 45, AN 15 & Amm chloride 40%  
*Ref:* M.M. Kostevitch, "Burning Ground", Imprim d'Art Voltaire, Paris (1927), p 36

### Function and Casualty Tests of Small Arms Ammunition

The purpose of these tests is to ascertain by firing in weapons of representative types whether the ammunition functions satisfactorily from the point of view of safety. Ammunition may be ballistically satisfactory, that is it may comply with individual performance specifications, such as velocity, pressure, accuracy, penetration, etc, yet be unfit for use in the field because of undesirable characteristics which jeopardize the safety of weapons.

Detailed description of such tests is given in  
*Refs: 1)* Anon, "Ordnance Proof Manual 7-15 1945)  

### Fungus Resistance Test for Fuzes

is briefly described in Vol 4, p D1094-L and fully described in US Standard MIL-STD-331 as Test No 110

### Funkenchronograph

Ger for Spark Chronograph, such as Siemens invented in 1845. It is not described in this Encycl, Vol 3, pp C304ff under CHRONOGRAPHS but is described in  
*Refs: 1)* H. Kast, SS 8, 90-1(1913)  
*3)* H. Rumpf, Explosivstoffe 5, 263(1957)

### Funkenkinematographie

Ger for Spark cinematography

### Funkenphotographie

Ger for Spark Photography

### Funkenzünder

Ger for Spark igniter, such as of Bornhardt, described in Beyling-Drekopf (1936), p 216
Functioning is the succession of normal actions from initiation of the first element to delivery of an impulse from the last element of the expl train (Ref 1). There are two types of functioning: high order and low order. The high order functioning consists of a deton, while low order functioning consists of a partial deton or a deflagration (burning). See Vol 4, pp D245-R to D252-L. If high order deton is required, and only deflagration occurs, then there is a dud.


Furacetic Acid. See Furfurylactic Acid, also known as Furfuralactic Acid

Furaldehyde. See Furfural

Furan and Derivatives
Furan or Furfuran, O\(\text{CH} = \text{CH} - \text{CH} = \text{CH}\); mw 68.075, colorless liq turning brown on standing; fr p \(-85.68\); bp 31.3; fl p \(-40^\circ\) (open cup), sp gr 0.937 at 20\(^\circ\), \(n_p\) 1.4214 at 20\(^\circ\), heat of combustion at const vol 500.1 cal; sl sol in w, sol in Et\(_2\)C, methanol, aloc, acet, eth, petrol eth, chl, benz, toluene & ethylene glycol. According to Ref 2, first prepd before 1870 by distillation of 2-furonic acid from strong bases. Attenberg (Ref 3) obtained it from "Holzöl", a dry distillation product of pine trees. Ref 1 gives other methods. The laboratory method (Ref 4) involves heating crude 2-furonic acid. Industrially, furfural vapors and steam are passed over catalysts such as mixed Zn and Mn chromite at 400\(^\circ\). Furan dec at about 670\(^\circ\), or as low as 360\(^\circ\) in the presence of Ni. It is very volatile and flammable. Furan is used in organic synthesis and may be catalytically hydro-
genated to tetrahydrofuran. Inhalation of large quantities or lengthy skin contact is apt to produce toxic results (Ref 1, p [34] & Ref 7, p 1005). Unstabilized furan slowly forms an unstable peroxide on exposure to air, so precaution should be used when distilling it.

Note: Acctg to US Rubber Co Report No 5 (1948-49), p 15, furan reacted with Nitroform to give a small quantity of a solid product which burned vigorously and was extremely sensitive to shock. (The report is available in PicArsnLibrary as U21965)


1,2,3,4-Tetraiodofuran, QC\(\text{I} = \text{Cl} - \text{Cl} = \text{Cl}\); mw 571.68, mp 165\(^\circ\), expl 262\(^\circ\). Prep'd by reacting aqueous \(\text{I}_2 / \text{KI}\) with 1,2,3,4-tetra-HgCl-furan

2-Nitrofuran, QC\(\text{H} = \text{CH} - \text{CH} = \text{C(NO}_2)\); mw 113.07, N 12.39%; vel-wh cryst (pet eth), mp 28\(^\circ\), sol in eth & w. Prep'd by nitration of furan in A\(_2\)O

Ref: 1) Beil 17, 28 2) R. Marquis, CR 132, 141 (1901)

3-Nitrofuran, QC\(\text{H} = \text{CH} - \text{C(NO}_2) = \text{CH}\); mw 113.075, N 12.39%; crys, mp 27\(^\circ\). Prep'd by heating 3-nitro-2-furonic acid, which was prep'd by oxidizing 3-nitro-2-methylfuran with K\(_2\)Fe(CN)\(_6\)/KAc at 100\(^\circ\)

Ref: 1) Beil, not found 2) I.J. Rinkès, RecTravChim 57, 390-4 (1938) & CA 32, 3980 (1938)
5,5'-Dinitro-2,2'-difuran,
\(\text{OC(NO}_2\text{)}_2\text{CH-CH}=\text{C-CH=CH=CN(O}_2\text{)}_2\); 
mw 224.13, N 12.50%); yel-brn prisms, mp 213-4°C. Found as a by product in the nitration of furan (Ref 2), and prep'd intentionally by heating 5-nitro-2-bromofuran with Cu (Ref 3) 
ChimPhys 83, 4, 233 (1905) 3) L.J. Rinkes, 
RecTravChim 50, 981-8 (1931) & CA 26, 
982(1932)

2,5-Dinitrofuran,
\(\text{OC(NO}_2\text{)}_2\text{CH-CH}=\text{C(NO}_2\text{)}_2\); mw 158.075, N 
17.72%, OB -40.5%; nds (w) or prisms (alcl), 
mp 101.5°C; sol in eth. Prep'd by nitrination of 2-nitrofuran at 100°C with 5g 1.2 nitric acid. It is an expl which is slightly less brisant and slightly more sensitive to impact than TNT. Heat of combustion is 432.2 kcal/m. Toxic to some people. Accdg to Gilman 
(Ref 4) it is an expl compd 
Refs: 1) Beil 17, 29 2) R. Marquis, CR 
135, 507 (1902) 3) W. McPherson, USP 
1827895 (1932) & CA 26, 849 (1932) 4) H. 
Gilman, OSRD Rept 350 (1942)

Furan Peroxide, \(\text{C}_8\text{H}_5\text{O}_4\); mw 168.15; crys, 
dec 100°C. Prep'd from furan and oxygen at 
RT (Ref 2). The same author (Ref 3) later 
reported a different compd, a solid which 
expl on heating, resulted furan, \(\text{O}_2\) & \(\text{CaCl}_2\) 
Refs: 1) Beil, not found 2) G.O. Schenck, 
Naturw 31, 387 (1943) & CA 38, 2336 (1944) 
3) G.O. Schenck, Ber 77B, 661-8 (1949) & 
CA 40, 6075 (1946)

Furan, Tetrahydro. See Tetrahydrofuran

1,2,3,4-Furan-Tetramercuro-Acetate, 
\(\text{C}_4\text{O(HgAc)}_4\); mw 1102.66, OB -36.3%; crys, 
dec 226-8°C. Prep'd by treating furan with aq 
HgAc. By grinding with 50% KOH, filtering, 
washing with water, and drying in vacuo over 
sulfuric acid there is obtd a gray product 
which tums white and expl on heating to 210°C; 
the gray material is more sensitive to heat 
than shock. By treating the tetra HgAc with 
hot, aqueous NaCl, there is obtd the tetra 
HgCl, dec 235°C. If instead of furan, 2-
furoic acid is reacted with HgAc, then CO2 
is liberated and a product comp of some of 
the tetra HgAc, but analyzing C 14.03, H 1.99 & 
Hg 66.3%, ppts. When given the KOH treat-
ment an expl gray compd results, analyzing 
C 5.64, H 0.64 & Hg 81.2% (which has less 
Hg than a tetra HgOH compd). On heating 
the gray material, an even more expl white 
material results, analyzing Hg 71.02% 
Refs: 1) Beil, not found 2) R. Ciusa & 
G. Grill, Gazz 57, 323-9 (1927) & CA 21, 
2686 (1927)

Furanols and Derivatives

2-Furanol, \(\text{OCH-CH-CH}=[\text{OH}]\); mw 84.07; 
crys, mp 80°C (dec 90°C). Prep'd by treating 
\(\text{OC(SO}_3\text{Na)}\text{CH-CH}=[\text{CO}_2\text{Na}\text{Na with aqueous} 
NaOH/KClO}_3\text{ in an autoclave at 200°C for 15} 
hrs. The compd has a pungent, actid odor, 
resinifies readily and turns brown on standing

3-Furanol, \(\text{OCH-CH-C(OH)}=[\text{CH}]\); mw 84.07; 
crys, mp 58°C. Prep'd either by Na/EtOH re-
duction of Na-Hg/base at 80°C for 2 hrs reduc-
tion of 2-bromo-3-furanol (yel, mp 85°C, prep 
from bromination of 2-furoic acid). The method 
could not be reproduced (Ref 4)

5-Nitroso-2-furanol, \(\text{OC(NO}_2\text{-CH-CH}=[\text{OH}]}\); 
mw 113.07, N 12.39%; yel crys, mp 176°C. 
Prep'd by reacting 2-furanol with HNO_2 at 0°C

2-Nitroso-3-Furanol, \(\text{OCH-CH-C(OH)}=\text{CNO}\); 
mw 113.07, N 12.39%; brn-yel crys, mp 151°C. 
Prep'd by reacting 3-furanol with HNO_2 at 0°C

5-Nitro-2-furanol, \(\text{OC(NO}_2\text{-CH-CH}=[\text{OH}]}\); 
mw 129.07, N 12.39%, OB -68.2%; yel crys, mp 92°C. Prep'd by oxidizing the nitroso compd 
with K_2Fe(CN)_6/KOH at 80°C, or by direct 
nitration of 2-furanol with HNO_2/H_2SO_4 at 
0°C. It does not steam distil or reduce Tollens Reagent

2-Nitro-3-furanol, \(\text{OCH-CH-C(OH)=CNO}_2\); mw 
129.07, N 12.39%, OB -68.2%; yel crys, mp
76°. Prepd by oxidation of the nitroso compd with K₂Fe(CN)₆/KOH at 80°. It steam distils but does not reduce Tollens Reagent.


Furfural and Derivatives

2-Furfural, Furfuraldehyde, Furfural Antoil or 2-Furaldehyde (2'-Oxo-2-methyl-furan or 2-Formyl-furan in Ger), CH₃CH=CHO; mw 96.09; colorless liq when pure but reddish-brown on exposure to light or air; fr p ~38.7°, bp 161–2° (760mm), 77° (37mm), 60–1° (18mm), fl p 68.3° (56.8°) — open cup, 140° — closed cup, sp gr 1.1544 at 25°, nD 1.52345 at 25°, ignition temp 315–37°; lower expl limit at 125°, 2.1% v/v in air, heat of combustion at constant pressure and volume 559.8cal; sol in w, alc & eth. Apparently first prepd by Döbereiner (Ref 2) as a by product of prepn of formic acid from sugar, sulfuric acid and pyrolysate, who called it "Künstliches Ameisenöl" but did not determine a formula. Stenhouse (Ref 3) prepded an identical oil in 1840 by digesting wheat grains with sulfuric acid but without the MnO₂; he analyzed it and established the empirical formula as C₆H₄O₂. Ref 1 lists many subsequent prepns.

A convenient laboratory prepn from corncoibs is given in Ref 8. Industrial prepn started in 1922 by Quaker Oats at Cedar Rapids, Iowa. Modern industrial prepns start with agricultural residues such as oat hulls, corn cobs, rice hulls, bran, etc, which have a relatively high pentosan content (Ref 10). In these processes pentosans are hydrolyzed to pentoses by acid digestion, and these spilt out water internally to form furfurals: HOCH₂(CHOH)₃CHO + OCH=CH-CH=CCHO + 3H₂O.

Furfural is used for making other derivatives of 5-membered rings, as a solvent in refining of lubricating oils, and to form copolymer resins with phenol.

Analytical procedures are found in Refs 6, 7, 12 & 14. Furfural may be detected by adding a few drops of aniline in acetic acid; an intense red color develops at once if present. Such other furfurals as the 5-methyl and 5-hydroxymethyl will also give a positive test. Furfural has low toxicity providing adequate ventilation and skin protection against contact is used.


3-Furfural or 3-Furaldehyde, OCH=CH-(CH=CHO)=CH; mw 96.09; liq, bp 144° (732mm), 71–3° (53mm), 66–8° (39mm), sp gr 1.111 at 20°, nD 1.4945 at 20°. Prepd by the Rosenmund reduction of the corresponding acyl chloride (Refs 2 & 3)

Refs: 1) Beil, not found 2) H. Gilman & R.R. Burnett, JACS 55, 2903 (1933) & CA 27, 3932 (1933) 3) K. Hayes, JACS 71, 2581–2 (1949) & CA 43, 7015 (1949)

Furfuralacetic Acid. See Furfurylacrylic Acid

5-Nitrofurural-2, O(NO₂)=CH-CH=CCHO; mw 141.08, N 9.93%; crystals, mp 35–6°, bp 132–40 (12mm). First prepd by Gilman (Ref
2) by nitration of furfurylidene diacetate and acid hydrolysis of the intermediate nitro-diacetate in overall 31% yield. A better yield was obtained by Witte (Ref 3) by nitration of furfural in the presence of PCI₃.


5-Nitrofurfural-3, OCN(NH₂)=CH-CH=CHO=CH, mw 141.08, N 9.93%; crys crystals mp 76°. Prepd by nitration of furfurylidene-3-diacetate.

Refs: 1) Beil, not found 2) H. Gilman & R.R. Burnner, JACS 55, 2903 (1933) & CA 27, 3932 (1933)

Furfural-N-nitriminoguanidine,
struction=CH=CH=CH=NNH(NH₂)=O, mw 197.165, N 35.52%; yellow ndls (alc), mp 220-4° dec.

Prepd in 90% yield by refluxing furfural and nitriminoguanidine in dilute alcoholic HAC at 100° for 15 mins.

Refs: 1) Beil, not found 2) W.B. Stillman & A.B. Scott, USP 2416233 (1947) & CA 41, 3488 (1947) 3) W.D. Kumler & P.P.T. Sah, JAmPharmAssoc 41, 375-9 (1952) & CA 47, 2132 (1953)

5-Nitrofurfural-N-nitriminoguanidine,
struction=CH=CH=CH=NNH(NH₂)=O, mw 242.15, N 34.71%, OB -66.1%; yellow ndls (alc), mp 249-50° dec.

Prepd in 95% yield by refluxing 5-nitrofurfural with nitriminoguanidine in dil alc HAC at 100° for 15 mins.

Refs: 1) Beil, not found 2) W.B. Stillman & A.B. Scott, USP 2416233 (1947) & CA 41, 3488 (1947) 3) W.D. Kumler & P.P.T. Sah, JAmPharmAssoc 41, 375-9 (1952) & CA 47, 2132 (1953)

α-Furfuraloxime (Prior to 1924 thought to be the β), OCH=CH-CH=C=O, mw 111.10;

β-Furfuraloxime (Prior to 1924 thought to be the α), H OH OCN=N

OCH=CH-CH=CH=NNH(NH₂)=O, mw 220.19, N 12.72%; crystals, exp 130°. Prepd by hypochlorite oxidation of the oxime at 0°.

Refs: 1) Beil 27, 463 2) G. Ponzio & G. Buschi, Gazz 36 II, 338-44 (1906) & CA 1, 842 (1907)

5-Nitro-furfuraloxime,
struction=CH=CH=CH=NO, mw 156.10, N 17.94%; crystals, mp 154° (121°). Prepd by nitration at 0° of the oxime (Ref 4).

For information concerning the isomeric nature see Ref 3.


5-Nitro-furfural Semicarbazone,
struction=CH=CH=CH=NNHCONH₂, mw 198.14, N 28.28%; crystals, mp 240° dec.

Prepd in nearly 100% yield by reacting the nitrofurfural with semicarbazide & HCl in dil alc NaA (Ref 2).

Refs: 1) Beil, not found 2) W.B. Stillman & A.B. Scott, USP 2416234 (1947) & CA 41, 3489
5-Nitro-furfural-3-semicarbazono, mw 198.14, N 28.28%; yt nds, mp 215°(dec, sl impure); sl sol in w. Prepd by heating 5-nitro-furfurylidene-3-diacetate with semicarbamide.HCl

Refs: 1) Beil, not found 2) H. Gilman & R.R. Burnet, JACS 55, 2903(1930) & CA 27, 3932(1933) 3) K. Hayes, JACS 71, 2581-2(1949) & CA 43, 7015(1949)

Furfuryl is the monovalent radical C₅H₄O— derived from Furfural. Exists in alpha- and beta- isomeric forms
Ref: Hackh’s(1944), 361-R

Furfuryl Alcohol or Furfurycabinol,
(2-Oxy-2-methyl-furan in Ger),

Furnaces and Ovens. Furnace is an apparatus or a chamber made of refractory material serving for heating, fusing or hardening materials by exposing them to high temps. The heat may be produced by burning gas, oil, alcohol, coal, wood or by electricity. Oven is an apparatus or chamber heated to lower temps than furnaces. Used in the laboratories and in the plants for drying various materials, including exps and proplnts

2-Furoamide, OCH=CH—CH=C(ONH$_2$); mw 111.10, N 12.61%; ndis (by subln), mp 142–3° (subl 100°). Prepd from the acid chloride and ammonia
Ref: 1) Beil 18, 276 & [268] 2) L. Bodart, CR 43, 393 (1856)

3-Furoamide, OCH=CH—C(ONH$_2$)=CH, mw 111.10, N 12.61%; crst, mp 169°. No prep given, presumably by treatment of the ethyl ester or acid chloride with ammonia
Ref: 1) Beil, not found 2) H. Gilman & R.R. Burtnner, JACS 55, 2893–6 (1933) & CA 27, 3932 (1933)

5-Nitro-2-furoamide,
O(ONO$_2$)=CH—CH=C(ONH$_2$); mw 156.10, N 17.95%; crst (alc), mp 161.5–2.0°; sol in alc. Prepd from the acid chloride and ammonia
Ref: 1) Beil 18, 288 2) R. Marquis, CR 137, 520 (1903) 3) C.D. Nenitescu & C. Bucur, RevChim, AcadRepPopulaireRoumaine 1, No 1, 155–64 (1956) & CA 52, 11811 (1958)

5-Nitro-N-nitro-N-methyl-2-furoamide,
O(ONO$_2$)=CH—CH=C(ON(ONO$_2$)CH$_3$); mw 215.12, N 19.54%, OB -63.3%; crst, mp 87–90°. Prepd by nitration at 0° of the 5-nitro-N-methyl-2-furoamide
Ref: 1) Beil, not found 2) H. Gilman & H.L. Yale, JACS 72, 3593–5 (1950) & CA 45, 1110 (1951)

Furidiazoles. See Oxidiazoles

Furoic Acid and Derivatives
2-Furoic Acid or Pyromucic Acid (Benzschleimsäure in Ger), OCH=CH—CH=CO$_2$H; mw 112.09, plates (w) or ndls (by subln), mp 133–4° (subl 100°), bp 230–2°; sol in w, alc & eth; heat of combustion at const vol 494.4 kcal/m. First observed in 1780 by Scheele in the dry distillation of HO$_2$C(CHOH)$_2$CO$_2$H (mucic acid). Prepd from similar source material (Ref 1) until Erdmann (Ref 2) oxidized furfuryl alc with KMnO$_4$ or ammoniacal silver soln
Ref: 1) Beil 18, 272 2) E. Erdmann, Ber 35, 1858 (1902)

3-Furoic Acid, OCH=CH—C(CO$_2$H)=CH; mw 112.09, plates (w), mp 121–2° (subl 110°); sol in alc, EtAc & hot w; steam distills. Found in the root of Phaseolus multiflouis (kidney bean) and the root wind of Evonymus atropurpureus
Ref: Beil 18, (439)

3-Nitro-2-furoic Acid, OCH=CH—C(NO$_2$)=CO$_2$H; mw 157.08, N 8.92%, OB -66.2%; crst, mp 125°. Prepd by oxidizing 3-nitro-2-methyl-furan with K$_8$Fe(CN)$_8$/KAc at 100°
Ref: 1) Beil, not found 2) I.J. Rinkes, RecTravChim 57, 390–4 (1938) & CA 32, 4980 (1938)

5-Nitro-2-furoic Acid, O(ONO$_2$)=CH—CH=CO$_2$H; mw 157.08, N 8.92%, OB -66.2%; yel plates (w), mp 184–5°; sol in alc, eth & boiling w. Prepd by heating furan-2,5-dioic acid with nitrosylsulfuric acid at 100° (Ref 2); hydrolysis of 5-nitro-2-cyano-furan (Ref 5) and oxidation of 5-nitro-furfural with CrO$_3$ (Ref 4). Forms a Silver salt which expl on heating (Ref 3)

5-Nitro-3-furoic Acid, O(ONO$_2$)=CH—C(CO$_2$H)=CH; mw 157.08, N 8.92%, OB -66.2%; crst, mp 138°. Prepd by nitration of 3-furoic acid or saponification the the ethyl ester (mp 56°) prepd by nitration of ethyl-3-furoate
Ref: 1) Beil, not found 2) H. Gilman & R.R. Burtnner, JACS 55, 2893–6 (1933) & CA 27, 3932 (1933)
5-Nitro-nitrate ethyl-2-furoate, 
\[ \text{OC(NO}_2\text{)=CH-CH=CCO}_2\text{CH}_3\text{H}_2\text{NO}_2\text{; }\text{mw } 246.13, \text{N } 11.38\%, \text{OB } -58.5\%; \text{crystals, mp 81-2\textdegree C}(\text{CH}_3\text{OH adduct), 124-5\textdegree C}(\text{CH}_3\text{OH.HAc adduct). Prepd from the alcohol by nitration with HNO}_3/\text{Ac}_2\text{O at } (\text{-})10 - (\text{-})5\text{\textdegree C. Obtd as the CH}_3\text{OH.HAc adduct, and may be freed of the HAc by treatment with pyridine.}
\]
Refs: 1) Beil, not found 2) H. Gilman & H.L. Yale, JACS 72, 3593-5(1950) & CA 45, 1110(1951)

**Furoyl** is the monovalent radical
\[ \text{CH-CH.O-CH=C.CO-} \] of Furoic Acid (qv). Do not confuse with Furfuryl (qv) and Furyl (qv)
Ref: Hackh's (1944), 362-R

2-Furoyl Azide, \[ \text{OCH=CH-CH=CCON}_3\text{; mw 137.10, N 30.65\%; plates (eth), mp 62.5\textdegree C (dec 110\textdegree C exp 182-3\textdegree C); sol in alc, eth, chl, acet, HAc & benz; insol in w. Prepd from the hydrazide and NaNO\textsubscript{2} /HAc (Ref 2). Used as a blowing agent in prep of resinous foams contg glycidyl polyethers of dihydric phenols (Ref 4).
\]

2-Furoyl Hydrazide, 
\[ \text{OCH=CH-CH=CC(C(ONH}_3\text{)}_2\text{; mw 126.11, N 22.22\%; prisms (alc), mp 80\textdegree C, bp 279\textdegree C (dec); sol in w (over 50/100 ml), alc, chl, benz & tol; dec in air. Prepd by refluxing ethyl furoate with hydrazine hydrate (Ref 2).}
\]

5-Nitro-2-furoyl-hydrazide, 
\[ \text{OC(NO}_2\text{)=CH-CH=C(O)NH}_3\text{; mw 171.11, N 24.56\%; crystals, mp 170-1\textdegree C (dec). Prepd from the acid and hydrazine hydrate in hot alc}
\]
Refs: 1) Beil, not found 2) H.L. Yale et al, JACS 75, 1933-42(1953) & CA 48, 4541 (1954)

2-Furoyl Hydroxamic Acid (Benzschleimsäure-hydroxylamid, in Ger), 
\[ \text{OCH=CH-CH=CC(O)NH}_2\text{H; mw 172.10, N 11.02\%; nlds (w), mp 128\textdegree C; insol in eth; sol in w, alc & HAc. Prepd from ethyl furoate and H2NOH in alc.}
\]

5-Nitro-2-furoyl hydroxamic acid, 
\[ \text{OC(NO}_2\text{)=CH-CH=CC(O)NH}_2\text{H; mw 172.10, N 16.28\%; OB -65.15\%; crystals, mp 169\textdegree C (dec). Prepd by treating the acid chloride with H2NOH.HCl. Decomposes on treatment with nitric acid at 0\textdegree C.}
\]
Refs: 1) Beil, not found 2) H. Gilman & H.L. Yale, JACS 72, 3593-5(1950) & CA 45, 1110(1951)

5-Nitro-2-(a-methyl)-furoyl hydroxamic acid, 
\[ \text{OC(NO}_2\text{)=CH-CH=CC(O)NCH}_3\text{; mw 186.125, N 15.05\%; crystals, mp 151-2\textdegree C. Prepd by treating the acid chloride with H2NOH.HCl. Decomposes on treatment with nitric acid at 0\textdegree C.}
\]
Refs: 1) Beil, not found 2) H. Gilman & H.L. Yale, JACS 72, 3593-5(1950) & CA 45, 1110(1951)

**Furoyl Peroxide or 2-Furoperoxide**, 
\[ \text{OCH=CH-CH=CCO}_2\text{OH; mw 128.09; colorless nlds, mp 59.5\textdegree C (may exp at 40\textdegree C). Prepd by shaking an eth soln of difuroyl peroxide at -5\textdegree C with acet-free methanol/NaOCl}_3\text{ and recryst from CCl}_4 \text{ at } -5\textdegree C. Most stable at 0\textdegree C, decompy by 360-450nm UV light and by inorganic or organic solids.}
\]
Refs: 1) Beil, not found 2) N.A. Milas & A. McAlevy, JACS 56, 1219-25(1934) & CA 28, 4413(1934)

**2,2'-Difuroyl Peroxide**, 
\[ \text{OCH=CH=C-C=CO}_2\text{C-C=CH-CH=C=O; mw 222.155; yellow nlds (alc), mp 86-7\textdegree C (dec); sol in eth, acet, HAc, chl, methanol, CCl}_4 & benz; insol in w & petr eth. Prepd from the
furanyl chloride and Na₂O₂ at 0°. Ordinarily stable but expl on heating over open flame; by impact or shock.

Refs: 1) Beil 18, [267] 2) H. Gelissen & J.D. Van Roon, RecTravChim 43, 362 (1924) & CA 18, 2515 (1924) 3) N.A. Milas & A. McAlevey, JACS 56, 1219-25 (1934) & CA 28, 4413 (1934)

2-Furanyl Nitrite, OCH=CH–CH=CCN; mw 93.09, N 15.05%; colorless oil (brows in air), bp 146-8°, 51° (23mm), sp gr 1.0790 at 25°, nD 1.4739 at 25°; sol in alc & eth. Prepd by dehydrating the aldoxime with boiling Ac₂O.

Refs: 1) Beil 18, 278 & [268] 2) P. Douglas, Ber 25, 1313 (1892)

5-Nitro-2-furanyl Nitrite, O₂(NO₂)=CH–CH=CCN; mw 138.09, N 20.29%; mp 65°. Prepd by dehydrating the aldoxime with boiling Ac₂O.

Refs: 1) Beil, not found 2) C.D. Nenitescu & C. Buicur, RevChim, AcadRepPopulaire-Roumaine 1, No 1, 155-64 (1956) & CA 52, 11811 (1958)

Further Equation of State. See Vol 4 of Encycl, p D277

Furanyl is the monovalent radical –C₄H₅O. Two isomers, alpha- and beta-, exist. Do not confuse with Furfuryl (qv) and fuse with Furfuryl (qv) and Furoyal (qv).

Ref: Hackh’s (1944), 262-R

Furylecrylic Acid and Derivatives

Furylecrylic Acid (Furfuralcetic Acid or Furacetic Acid), O₂(=C₄H₅O)=CH·CH·CH·CH·CO₂H; mw 138.12. Exists as stable and labile isomers. The stable form: ndls (w), mp 141°, bp (with quick heating) 255-65° (286°); sol in alc, eth, benz, HAC & hot w; steam distils. Can be prepd by refluxing furfural with NaAc (Reps 1, 2 & 4). The labile form: prisms & plates (benz), mp 103-04°; sol in benz & hot w. Was prepd by refluxing furfuridinmalonic acid with Ac₂O and recryst as its piperidine salt from benz (the salt of the stable form is more sol in benz (Ref 3)

Furylecrylic acid can be used for prep of some expls (See below)


5-Nitro-β-furylecrylic Acid, O₂(NO₂)=CH·CH·CH·CH·CH·CO₂H; mw 183.12, N 7.65%; no props are reported. Can be prepd by nitrating furyle-β-acrylic acid with nitric acid in Ac₂O.

Its lead salt is expl.

Refs: 1) Beil, not found 2) R. McGill, OSRD Rept 830 (1942), p 34

Lead 5-Nitro-furyle-β-acrylate,
(Q(NO₂)=CH·CH·CH·CH·CO₂Pb; mw 571.42, OB –64.4%; om solid, mp (blackens at 170°).

Prepd by treating with lead acetate the 5-Nitrofuryl-β-acrylic Acid (Ref 2). It is an expl comparable in sensitivity to TNT, but much less powerful (<50% TNT, by ballistic mortar test). Its thermal stability is satisfactory and it is only moderately hygroscopic.

Refs: 1) Beil, not found 2) R. McGill, OSRD 830 (1942), p 34

Furyle-β-acryloyl Peroxide,
(Q·CH·CH·CH·C·CH·CO₂)², mw 274.23, O 35.01%; wh ndls (transparent at standing), mp 104°; sol in acetic & EtAc; sl sol in eth. Prepd from furyle-β-acryloyl chloride and NaOH. Expl on heating.

Refs: 1) Beil, not found 2) N.A. Milas & A. McAlevey, JACS 56, 1219-25 (1934) & CA 28, 4413 (1934)

Furfuryl Carbinol. See Furfuryl Alcohol in this Section

Furyle-β-(2,4,6-trinitro)styrene,
O₂(=C₄H₅O)=CH·CH·CH·CH·C₆H₄(NO₂)₃, mw 305.21, N 13.77%; crs, mp 128°. Prepd by condensing furfural with TNT in pyridine, using piperidine as catalyst.

Fusain (Mother of Coal or Mineral Charcoal). See Vol 3 of Encycl, p C353-R and in CondChemDict (1961), 521-R. It reduces the caking properties of the coal in which it occurs.

Fuse. See FUSES

Fused Salts. Salts (ie ionic compds) in the molten state. High temps are usually involved in maintaining the molten condition. Common salt is the principal ingredient of many fused salts. They have been used as a base for circulating liquid fuels in nuclear reactors and for many other purposes. Refs: 1) CondChemDict (1961), 521-R & 522-L

Fusee. (Amer) (Pronounced “fu-zee”). An obsolete term for a fuse or detonator. At present, the name applies to a long-burning flare (about 20 minutes) used mostly for railroad emergency signalling. It has the appearance of a big candle and can be stuck into a wooden tie by means of a spike. It is ignited by scratching since a match type igniter forms a part of the fusee.

An example of a miliary use is the Navy Light MK I Mod 1 (See Fig). This device is designed to produce a bright light for recognition and signalling purposes. The Mod number indicates the different colors of flame produced. For instance, Mod 1 gives off a blue signal for 75 seconds, whereas Mod 0 gives off a red signal and burns for 135 secs. The light can be seen up to 3 miles in clear weather. Refs: 1) GlossaryOrdn (1959), 125-R 2) Anon, "Pyrotechnic, Screening, and Marking Devices", OP-2213, Dept of Navy (1969), pp 5-29 & 5-51

Fusée. French word which corresponds to Amer fuze, fuse, fusee, flare or rocket. Ref: Same as Ref 1 under next item.

Fusées. Following is the list of various Fr fusées:

- Fusée antichar — Antitank rocket
- Fusée d'artillerie — Artillery fuze
- Fusée d'atterrissage — Landing flare
- Fusée de Bickford — Bickford fuse
- Fusée de bombe — Bomb fuze
- Fusée de concussion — Concussion fuze
- Fusée de culot — Base fuze
- Fusée détonante — Detonating (or percussion) fuze
- Fusée à double effet — Combination fuze
- Fusée à durée ou Fusée à temps — Time fuze
- Fusée à effet retardé — Delay fuze
- Fusée éclairante — Illuminating flare
- Fusée éclairante à parachute — Parachute flare
- Fusée éclatante — Star flare
- Fusée à étages — Multiple-stage rocket
- Fusée fusante — Time fuze

Fig Navy Light Mk I Mod 1
Fusée instantanée – Instantaneous fuze
Fusée lente – Slow match
Fusée d’ogive – Nose fuze (Point detonating fuze)
Fusée à obus – Shell fuze
Fusée percussante – Percussion (impact) fuze
Fusée à proximité radioélectrique – Proximity (or VT) fuze
Fusée retardée – Delay fuze
Fusée de signalisation – Signal flare or rocket

Fusée-Type Flares. See Oharr (1946), p 306 and in this Vol, p F64, under Flares

Fusehead or Electric Matchhead. A flashing (igniting) element used in electric blasting caps and detonators. It is a combination of bridge wire, igniter head (drop or cylindrical chge) and lead-in wires. There are several types, and the following are described in Vol 4 of Encycel:

p D138-R, Fig 8 – Low-tension Fusehead for Electric Detonator
p D739-R, Fig 10 – British Fusehead in Electric Delay Detonator
p D740-L, Fig 11 – British Fusehead in Electric Short Delay Detonator
p D741, Fig 12 – The sequence of events in firing Electric Detonator
p D807, Fig 71 – Special Military Electric Cap M6 with bridge wire surrounded by cylindrical ignition chge of LS/Barium, followed by LA and RDX
p D808, Fig 72 – Medium Energy EBW (Explooding Bridge Wire) Detonator with Wollaston Wire
p D808, Fig 73 – EBW Plug (HV-1) Modified for Very High Voltage
p D809, Fig 74 – EBF Detonator Design for High Voltage Application
p D846, Fig 1-27 – Navy Electric Detonator, Mk46 Mod 0 with bridge wire located in a loose cylindrical charge congl 75/25-DAzDNPh/K chlorate mix
p D847, Fig 1-28 – Navy Electric Detonator Mk51Mod0 with bridge wire located in flash chge XC-9
p D847, Fig 1-29 – Amy Electric Detonator M36 with bridge-wire located in a cylindrical chge of MF milled in 2.4% soln of NS in bural acetate
p D848, Fig 1-30 – Amy Electric Detonator M48 with colloidal graphite bridge, which ignites Milled LA and this detonates Dextrinated LA and PETN
p D848, Fig 1-31 – Amy Electric Detonator T20E1 with tungsten wire bridge, which ignites colloidal LA, and this detonates dextrinated LA & PETN
p D849, Fig 1-31 – Electric Delay Detonator T65 with colloidal graphite bridge, which ignites Lead Mononitroresorcarinato, which is followed by Normal Lead Styphaete, 70/30-Lead Peroxide/Boron, 90/10-Barium Chromate/Boron, Dextrinated LA and RDX
p D850, Fig 1-33 – Button Type Electric Detonator T62 with colloidal graphite bridge, surrounded by Colloidal LA, which is followed by Dextrinated LA and PETN
p D855, Fig 1-43 – Navy Electric Fuze Primer M112Mod0 with bridge wire surrounded by flash charge XC-9, which is followed by base chge of 75/25-DAzDNPh/K chlorate
p D855, Fig 1-44 – Navy Electric Fuze Primer Mk121 with conductive carbon bridge, surrounded by ignition chge of LS/Lacquer followed by flash charge of XC-9 and base chge same as in Mk112Mod0
p D856, Fig 1-45 – Navy Experimental Spray Metal Electric Fuze Primer with bridge wire attached by “spray” metal (method developed at NOL and described on p D856-R), followed by ignition chge of dry LS/pressed at 3400psi, spacer and base chge of PETN

Accdg to Fordham (1966), p 116, the first successful fusehead was invented in Germany by Krannichfeld. The “sandwich” type construction is now used in many countries, including Great Britain. It is illustrated in Fig 10.2 on p 117. The manuf of such fuseheads in Great Britain is described on pp 117-1 of Fordham. Assembly of electric detonators using these fuseheads is described on pp 119-21 with Fig 10.5

German fuseheads and their manuf are de-
Fusehead Bond of Ingram contained, in addition to a binding agent, an aromatic compound containing a nuclear-bound iodine atom attached to at least one terminal oxygen atom, such as iodoxy acid iodoxy compounds of benzene (toluene azido benzene or its derivatives). The explanation of these derivatives as determined by the 5 sec expln temp test (Ref 2) has not exceeded 305°F.

May be used for both low-tension and high-tension electric blasting initiators (Ref 1). Refs: 1) L.K. Ingram, USP 2241496 (1941) 2) A.J. Clear, "Standard Laboratory Procedures for Determining Sensitivity, Brisance and Stability of Explosives", PATR 3278 (1965), pp 7-8 & 39 with Fig 8

Fuseheads, Electrical Characteristics of

A study was undertaken with a view to determine the basic mechanism of failure in series firing ability. The excitation time, transfer time and total time of three different types of squibs: (i) with LMNR as base (ii) with Lead Dinitro-ortho-cresol (LDNOC) as base and (iii) with charcoal plus potassium chlorate as base were determined.

It was found that for the charcoal based squib, the transfer time was almost double the initiation time. This large transfer time obviously takes care of the variations in the excitation timings due to different factors in the manufacture of squibs. This ensures continuous flow of current thru all the squibs connected in series until the time the most sensitive squib breaks the circuit. In the case of LMNR and LDNOC fuseheads the transfer time was found to be quite low and the total time of some of the fuseheads was less than or equal to the excitation times of some others in the same group. Such squibs when connected in series caused failures in series firing. As a confirmation to this theory, a retardant was introduced in the LMNR fuseheads to increase the transfer time, and no misfires were noted.

Ref: 1) K. Bhujanga Rao et al, R&D Dept of Indian Detonators Ltd, Hyderabad, India
2) Expis&Pyrots 4(4), 1971

Fuseheads, Pressures Produced by Their Combustion was discussed by I. Ito et al of Univ of Kyoto, Japan in Suiyokaishi 15(1), 29-32 (1963) and abstracted in CA 62, 12966 (1965). The pressure produced by fusehead contg DAzDNPh was 70kg/sq cm, while the fusehead with mixt of PbDNResorcin, Pb modanate & K chlorate produced 50kg/sq cm.

Fuse, Hot Wire, Lighter Used in Pyrotechnics. See Vol 4, p D762-L

Fuse Ignitors or Lighters Used in Ordnance Items. See Vol 4, pp D768 & D769-L

Fuse Lighter "Pyrocote". See Vol 4 of Encycl, p D763-L

Fuse Lighter "Pyrofuse". See Vol 4, p D762-R

Fuse Lighters Used in Pyrotechnics. See Vol 4, p D762

Fuse Lighter "Thermalite Ignitacord". See Vol 4, p D762-R

Fuse, Liquid-Metal, Self-Healing. When mercury replaces the filament of an exploding-wire fuse, it will break contact by vaporizing upon application of an overvoltage, then make contact by condensing when the overload disappears. This happens within a heavy-walled capillary tube connecting two reservoirs (see sketch). Evaporation forces mercury from the capillary to break the circuit. Experimental quartz glass and pyrex tubes exhibit da-

Fuse Oil. A clear, colorless, volatile, poisonous, oily mixture with a disagreeable odor, consisting largely of amyl alcohols (See Vol 1 of Encycl, pp A394-R to A395-R), of which isopropyl (isobutyl carbrol) and active amyl alcohol (2-methyl-1-butanol) are chief constituents. Other alcohols, as well as aldehydes, esters and acids are present but no normal primary amyl alcohol (1-pentanol). Typical spec for refined product: sp gr 0.811-0.815 (20/20°F), fl p (open cup) 123°F; dist range ca 115-135°F; sol in w, alc & eth; miscible with gasoline. Can be obtb as a by-product in the alcoholic fermentation of starch or sugar-contg materials, such as potatoes, beetroots, grapes, grain, etc. Used as gela-

FUSE

(Not to be confused with FUZES)

Fuses may be defined as tube- or cord-like containers filled with deflagrating or detonating materials. Both the outer sheathing material and the weight and type of expls contd will depend upon the required usage. Deflagrating expls or propellants burn whereas detonating expls detonate to produce blast, shock, and fragments. A fuse designed using deflagrating expls is known as a safety fuse, and that designed using detonating expls is known as detonating fuse. Care should be exercised in the use of fuses because of the difference in output of the two major types. Other characteristics which differentiate between deflagrating and detonating expls are: 1) reaction rate (usually a ±10% variation) 2) potential hazard 3) Department of Transportation shipping class 4) Department of Defense Compatibility Class 5) Department of Defense Hazard Class. The reaction rate of deflagrating expls (ie safety fuse) is normally 90 or 120 seconds per yard (Ref 2). Burning rate of delay cords depends upon composition. The potential hazard of this type is based on the fact that the rate of flame propagation increases with increasing pressure from gases released in a confined space. The shipping class is C, compatibility B, E, or H and hazard class 1 (Ref 1). With the detonating types, the reaction rate is normally 17000 to 26000 feet per second. Detonation rate of a particular expl increases with increased core density. The hazard inherent in this type is the high velocity fragments resulting from sheath rupture. Shipping class is A or C, compatibility class I or D and the hazard class 7 or 2 (Ref 1). The major types of expls used in fuses are illus-
Fuses, Bickford. See Vol 2 of Encycl, p B112-L

Fuses, Bickford Cordeau. See Vol 2 of Encycl, p B112-R

Fuses, Detonating. Detonating fuse, Type B material (Fig 1), is usually referred to by the trade name, Primacord (registered trade name of Ensign Bickford Co) (See Vol 2 of Encycl, p B112-R and Vol 3, p C529-R). It is widely used for initiating expls in quarrying, mining and general blasting operations.

Military uses include demolition-charge harnesses, warhead assemblies, and aerospace applications such as missile-stage separation and destruct systems. Approx 500 million feet per year of detonating fuse is manufd in the US, with worldwide consumption approaching 1 billion feet (Ref 2).

The expl core, contg either PETN or RDX is covered by various combinations of materials such as textiles, waterproofing compds, plastics, rubber, etc. The covering may be wire reinforced (Ref 2).

Type C materials (Fig 1) are smaller in diam and contain less expl. Four types are available: Primalene (Ensign Bickford Co), Mild detonating fuse (MDF), Pyrocore (du Pont Company) and delay fuse.

Type D material (Fig 1) is made with a metal tube covered by a polyethylene sheath and many layers of woven fiberglass. It is called "controlled detonating fuse" (CDF) (Ref 2) and used mainly in aerospace applications to transfer a detonation stimulus from an initiating element to some remote expl function.

Type E material (Fig 1) is called flexible linear shaped charge (FLSC). See shaped charge

Ref/s: 1) FM-25, "Explosives and Demolitions", Department of Army (October 1963) 2) Sidney A. Moses, "Linear Explosives", Ordnance Vol LVI, No 311, 355–57 (March-April 1972)

Fuses, Miner's. Same as Bickford Fuse described in Vol 2, p B112

Fuses, Safety. The safety fuse (Type A, Fig 1), consists of a core of granular Black Powder sheathed with various protective layers. It is used mainly for mining and quarrying operations. The flame developed is transmitted along a preselected path to the pyrotechnic charge, where it can either initiate the charge directly or initiate one or several squibs that are used as charge igniters.

Two types of fuse are in common use by the US Army: (1) blasting time fuse that has a spiral wrapped outer cover usually colored orange and (2) safety fuse M700 that has a smooth green plastic cover with length markers of abrasive material (so they can be felt in the dark). These two types of fuse are shown in Fig 2 (Ref 1).

Safety fuse can be ignited in several ways:

1) Matches. Ordinary matches are frequently used to light a single line of fuse. The fuse must be split, taking care not to dislodge the BkPdr filler. The match is applied so that its initial flare ignites the fuse.

2) Military Fuse Lighters. The military lighters provide a method of positive ignition of safety fuse even under extreme environmental conditions (See Vol 4 of Encycl, Sect
**Safety Fuse**: Introduction (p 136); manuf (pp 136–38 with Fig 13.1); properties (p 139); testings (pp 139–40)

**Instantaneous Fuse** (p 140)

For some purposes, especially in fireworks, when instantaneous, or almost instantaneous, transmission of flame is required without detonation, such a fuse is used. It consists of a highly combustible thread (often made from nitratated paper) inside a tube of known diam. The thread (serving as a core) occupies only a small part of the cross section of the tube, so that the gases can penetrate along it freely. The high speed of burning is caused by the rapid passage of hot gases along the tube, igniting the core well in front of the portion already consumed. The rate of burning is not easily controlled, but the uses to which the fuse is put are such that this is not of great importance. Threads coated with BkPdr may be used instead of nitratated paper.

These fuses are usually made in small quantities by simple hand method

Ref: Fordham (1966), 131–40

**Fuse Test.** See Test a) in Vol I, pp XXII–XXIII, under SENSITIVITY TO FLAME, HEAT, SPARKS, ELECTROSTATIC DISCHARGES, ETC

**Fusible Alloy** is an alloy melting at a temp lower than the mean mp of the constituents (Ref 1). The term is generally applied to alloys melting below 450°F(233°C). They can be binary, ternary, quaternary, or quinaries of Bi, Pb, Sn, Cd, Indium and less frequently other metals. Eutectic alloys are relatively few in number and are the particular combs that have definite and minimum mp as compared with other mixes of the same metals. Table 1 of Ref 2 lists 17 eutectics of mp’s ranging from 46.89°F to 248.0°F. Of these the Lipowitz’s eutectic, melting at 70.0°F is well known. It consists of Bi 50, Pb 27, Sn 13 & Cd 10%. Table II of Ref 2 lists 13 non-eutectic alloys with mp’s ranging from 64.0 to 159°F. Table III of Ref 2 lists eight common fusible alloys of mp’s 70 to 138°F. Of
these Wood's alloy (mp 71°, contg Bi 50, Pb 24, Sn 14 & Cd 12%) and Rose's alloy (mp 100°, contg Bi 50, Pb 28 & Sn 22%) are well known in chem labs

The chief industrial uses of fusible alloys are for fusible automatic sprinklers, anchoring bearings and bushings, for heat transfer liquids, for glass to metal seals, etc (Ref 2) Refs: 1) Hackh's Dict (1944), 363-L 2) CondChemDict(1961), 522-23; (1971), 30(Alloy, fusible), 539 (Wood's metal)

Fusible Metals. Any metal or alloy of relatively low mp, such as Na, K, Pb, Sn, etc Ref: Hackh's Dict (1944), 363-R

Fusil. Fr for rifle

Fusinite(e). A Ger coal (Kohle) illustrated in Ref Ref: Ullmann 9(1957), 168

Fusion. Usually a synonym for melting or flowing together, eg, the transformation of a solid into a liquid by the application of heat and w/o using a solvent other than a flux (Ref 1). Since melted substances tend to mix readily, the word has assumed the meaning of "melt" and "blend". The so-called fusion of protons to form helium as utilized in the hydrogen bomb indicates a union of two or more protons to form an element with great liberation of energy

A brief description of fusion- or hydrogen bomb (H-Bomb) is given in Vol 1 of Encycl, p A499, under Atomic (or Nuclear) Bomb Refs: 1) Hackh's Dict(1944), 363-R 2) CondChemDict (1961), 523-R(Fusion); 815-L(Nuclear energy); 815-R(Nuclear fusion); (1971), 407(Fusion)

Fusion Mixture. A mix of Na and K carbonates used to fuse insol substances of high mp's (such as ores) in order to render them soluble in the form of double carbonates. Fusion can also be achieved by heating insol substances with Na or K hydroxides Ref: Hackh’s Dict (1944), 363-R

Fusion Reaction is described briefly in Vol 1 of Encycl, pp A500 to A504-L, under "Atomic (or Nuclear) Energy; Atomic (or Nuclear) Explosions". This was described by C.G. Dunkle, formerl of Picatiny Arsenal

See also "Nuclear Reaction" in CondChemDict (1961), 815-R & 816-L ;(Compare with Fission Reaction)


Fuze Catalog of 1970 is an up-date of the 1959, Army, Navy, Air Force Fuze Catalog, which lists technical and reference info for all fuzes and fuze expl components, both standard and developmental. There are 2100pp divided into Volume 1. Current Fuzes (classified); Volume 2. Obsolete and Terminated Fuzes (unclassified); and Volume 3. Fuze Explosive Components (classified) Refs: 1) MIL-HDBK-137, Fuze Catalog, 20 Feb, 1970 2) Expls&Pyrots 3(8)(1970)


Fuze, Fluetic. See Fluidics for Ordnance, Vol 6, p F112

Fuze, German (Zünder). Many fuzes were developed in Germany before and during WWII. They were subdivided into Bombenzünder (Bomb Fuzes) and Granatenzünder (Projectile Fuzes). They are listed, including numerous illustrations on pp Ger 54-R to Ger 63-R of PATR2510(1958). Five other refs are given on p Ger 63-R
Fuze Handbook, Up-dated  The engineering textbook on fuze design is arranged in three parts: (1) Fundamental principles (covers purposes, general functioning, design considerations, initiation, and explosive train) (2) Basic arming actions (describes all arming principles) and (3) Fuze design (discusses the various types of fuzes, such as artillery, bomb, and mine and covers fuze testing)

The new edition updates the one written a dozen years ago. Among the new material: dual arming, design for rain insensitivity, analog computer analysis, electric power sources including RC circuits, electric, fluidic, and pneumatic arming, detached lever escapements, spiral unwinder, enlarged design guidance, and complete list of JANAF Journal Articles


**FUZES**

(Not to be confused with FUSES)

The definition of the term fuze is given in Vol 4, p D879-L under Introduction; and definitions of various types of fuzes are given under the "List of Fuzes", pp D879-L to D884-R

The definition given by Ordn Dept after Spanish-American War was: "A mechanical device, with or without explosive elements, used to explode a shell, bomb or other type of projectile". The British name for an unloaded fuze is pistol

Military Fuzes may be subdivided into Artillery Fuzes, Demolition Items Fuzes, Hand Grenades Fuzes, Land Mines Fuzes and Bomb Fuzes

A. Artillery Fuzes (pp D885 to D887-L) may be subdivided into: PD(Point Detonating) PI(Point Initiating), T(Time), SQ(Superquick), TSQ(Time, Superquick), MT(Mechanical Time) and MTSQ(Mechanical Time, Superquick)

Following Figs are for various fuzes:
Fig 1-73 on p D887 is for PD, SQ Mk 27 Fuze
Fig 1-74 on p D889 is for PD, SQ, Delay, M5A1 Fuze
Fig 1-75 on p D890 is for PD M52A1 Fuze
Fig 1-76 on p D892 is for PD, TSQ, M54 Fuze
Fig 1-77 on p D893 is for PD, M56 Fuze
Fig 1-78 on p D894 is forTime(Fixed)65A1 Fuze
Fig 1-79 on p D895 is for PD, M75 Fuze
Fig 1-80 on p D896 is for TSQ, M77 Fuze
Fig 1-81 on p D897 is for PDGP, M78 Fuze, where CP means Concrete-Piercing
Fig 1-82 on p D898 is for Time, M84 Fuze
Fig 1-83 on p D899 is for PD, M89 Fuze
Fig 1-84 on p D900 is for PI, M90A1 Fuze
Fig 1-85 on p D901 is for PD, M50A1 Fuze
Fig 1-86 on p D903 is for PD, M557 Fuze
Fig 1-87 on p D905 is for PD, XM593 Fuze in unarmed position
Fig 1-88 on p D906 is for the above Fuze in armed position
Fig 1-89 on p D907 is doe MT, M43A4 Fuze
Fig 1-90 on p D911 is for MTSQ, M548 Fuze
Fig 1-91 on p D912 shows "explosive train" for the above fuze
Fig 1-91a on p D912 is for MTSQ, M564 Fuze

**BD(Base-Detonating) Artillery Fuzes:**

Fig 1-92 on p D913 is for BD, M58 Fuze
Fig 1-93 on p D914 is for BD, M66A2 Fuze
Fig 1-94 on p D914 is for BD, M72 Fuze
Fig 1-95 on p D913 is for BD, M91A1 Fuze
Fig 1-96 on p D916 is for PIBD, M530A1 Fuze
Fig 1-97 on p D918 is for BD, M578 Fuze

**Proximity or VT (Variable Time) Artillery Fuzes:**

Fig 1-98 on p D919 is for Typical VT Fuze and are listed on p D921 without Figs the following:

Fuzes, Proximity:
M504A1, M504A2, M513, M513A1, M513B1, M514, M514A1, M515, M516, M516A1, M516B1, M516B2, M517 and M532 for Mortars
Recoilless Rifles Projectile Fuzes.
They are similar to those used in ordinary artillery fuzes. Nineteen fuzes are listed on pp D921-R & D922-L, without giving their Figs.

Mortar Projectile Fuzes.
They are similar to those used in artillery projectiles.
Eighteen fuzes are listed on p D922 without giving the Figs.

Foreign Artillery Fuzes of WWII.
British. Info is confidential.
French. No info available.
German. The name is Geschusszünder instead of erroneously varityped Gessoszünder.
A complete list of German fuzes used during WWII, including their Figs, is given in:
1) TM 9-1985-3 (1953), p 547-608 and
2) PATR 2510 (1958), p 50 to 64, Ger 58 to 64
(See also at the end of this Section)
Italian (Spolletti). The list of fuzes given on p D923 of Vol 4 includes those described in
TM 9-1985-6 (1953), pp 133-134
Japanese. The list of fuzes given on pp D924 & D925 includes those described in
Russian (Vzryvateli and Snariadniiye Trubki). More complete list than on p D925 is given in
PATR 2145 (1955), pp Rus 7 & Rus 8
Spanish. No info.
Swedish. No info.
Swiss. No info.

B. Fuzes for Bombs are briefly described in Vol 4, Section 6, Part C, pp D967 to D1010
They may be subdivided into:
Bomb Nose Fuzes, such as shown in:
Fig 4-1 on p D968 for Fuze, AN-M103A1
Fig 4-2 on p D970 for Fuze, AN-Mk219
Fig 4-3 on p D971 for Fuze, Mk243Mod0
Fig 4-4 on p D972 for Fuze, M904E2
Fig 4-5 on p D974 for Fuze M197
Fig 4-6 on p D975 for Fuze, AN-M159
Fig 4-7 & Fig 4-8 on p D977 for Fuze, M157
Fig 4-9 on p D978 for Fuze, AN-M173A1
Bomb Tail Fuzes, such as shown in:
Fig 4-10 on p D980 for Fuze, AN-M100A2
Fig 4-11 on p D982 for Fuze, M115
Fig 4-12 on p D983 for Fuze, AN-Mk228
Fig 4-13 on p D985 for Fuze, M123A1
Fig 4-14 on p D986 for Fuze, M123A1 (Operation)
Fig 4-15 on p D987 for Fuze, M132
Fig 4-16 on p D989 for Fuze, M906

Bomb MT (Mechanical Time) Fuzes, such as shown in:
Fig 4-17a on p D991 for Nose MT Fuze, AN-M146A1 (Unarmed) and
Fig 4-17b on p D992 for above fuze (Amed)
Fig 4-18 on p D994 for Nose MT Fuze, M135A1
Fig 4-19 on p D995 for Nose (or Tail) Fuze, M907

Bomb Proximity or VT Fuzes, such as shown in:
Fig 4-20 on p D996 for VT Fuze, Ring Type and Bar Type
Fig 4-21 on p D997 for Nose VT Fuze, AN-M166

Bomb Hydrostatic Fuzes, such as shown in:
Fig 4-22 on p D999 & Fig 4-23 on p D1000 for Tail Hydrostatic Fuze, AN-Mk230

Bomb Nonstandardized Fuzes, such as shown in:
Fig 4-24 on p D1001 for Nose MT Fuze, M129
Fig 4-25 on p D1002 for Nose MT Fuze M130
Fig 4-26 on p D1004 for Nose MT Fuze, M131A1

Bomb Pyrotechnic Fuzes, such as shown in:
Fig 4-27 on p D1006 for Nose Fuze, AN-M146A1 and in
Fig 4-28 on p D1007 for its Arming Mechanism

Fuzes for Demolition Items
Fig 1-99a on p D926 is for Bullet Impact Fuze, M1A1 for Demolition Snake M3. It can also be used with "bangalore torpedoes", described in Vol 2 of Encycl, p B16-R

Fuzes for Hand Grenades:
Fig 1-100 on p D927 is for Hand Grenade Fuze, M215
Fig 1-101 on p D927 is for Hand Grenade Fuze, M217
Fig 1-102 on p D928 is for Hand Grenade Fuze, M201A1

Fuzes for Land Mines
Fig 1-103 on p D929 is for Antipersonnel Mine, NM, M14 w/Integral Mine Fuze
Fig 1-104 on p D930 is for Antipersonnel Mine, M2A4 w/Mine Fuze, M6A1
Fig 1-105 on p D931 is for Antipersonnel Mine, M16 w/Combination Mine Fuze M603
Fig 1-106 on p D931 is for Antitank Mine Fuze, M603(T17E2)
Fig 1-107 on p D932 is for Heavy Antitank Mine, M6A2 w/Mine Fuze, M603
Fig 1-108 on p D932 is for Light, HE, Antitank Mine M7A2 w/Mine Fuze, M603

Refs for Fuzes. See the following refs listed in Vol 4 of Encycl, pp D1025ff:
p D1025-L (Ref 17); p D1025-R (Ref 19); p D1025-R to D1026-L (Ref 23); D1026-R & D1027-L (Ref 27a); D1027-L (Ref 27b); D1027-L & R (Ref 28a); p D1027-R (Ref 28b);
D1027-R & D1028-L (Ref 29); D1028-R (Ref 30a); D1028-R (Ref 30c); D1028-R (Ref 31);
D1028-R to D1029-L & R (Ref 32); D1031-L (Ref 35); D1031-L & R (Ref 40); D1032-L (Ref 41);
D1032-R (Ref 45); D1033-L & R (Ref 45e); D1034-R to D1035-R (Ref 51a); D1036-R to D1037-L (Ref 52); D1037-L (Ref 58)

Picatinny Arsenal Technical Reports on Fuzes are listed in Vol 4, pp D1057-R & D1058-R.
Include also J.M. Kaschak, PATR 3377(1966) (Production engineering activities relating to the M423 and XM427E1 fuzes)

Picatinny Arsenal Memorandum Reports on Fuzes are listed on pp D1058-R to D1560-L


Fuzes and Fuze Components, Environmental and Performance Tests For. The following tests are described in MIL-STD-331 (10 Jan 1966) and Change Notice 1 (24 July 1967); Change Notice 2 (11 December 1967); Notice 3 (11 June 1969); Notice 4 (16 April 1971); Notice 5 (1 June 1971); and Notice 6 (20 March 1972): 1. Accidental Release (Low Altitude, Hard Surface), Test 206 is also briefly described in Vol 4 of Encycl, p D1092-L 2. Air Delivery, Simulated (Parachute Drop) Test T213 is briefly described in Vol 4, p D2092-R and its revision is given as Test 117 in Notice 3, 11 June 1969 3. Catapult and Arrested Landing Test 212 is briefly described in Vol 4, p D1092-R 4. Detonator Output Measurement by Lead Disc Test 302 is also briefly described in Vol 4, p D1092-R 5. Dust Test 116.1 (Notice 5). A brief description of similar test, entitled "Sand and Dust Test" is given in Vol 4, p D1097-L. The "Dust Test" described in Notice 5 of 1971 is intended for use during development and production of fuzes to check their ability to withstand exposure to a fine dust environment. The test consists of placing bare live fuzes in a special chamber, provided with accessories to control dust concentration, air velocity, temperature and humidity. The free air space in the chamber must be sufficient to provide adequate circulation of the dust. Not over 15% of the cross-sectional area and 20% of the volume should be occupied by fuzes. The dust used in the test shall be of angular structure and consist of at least 97% silicon dioxide (SiO2) and shall have the following size distribution as dned by wt using US Std Sieves: 100% pass thru 100-mesh, 98% thru 140, 90% thru 200 and 75% thru 325-mesh screen. Details of the test are given on three pages. It is time consuming because it consists of several phases: 1) Room Temperature Phase (duration not given); 2) Transition Phase (duration 16 hrs); 3) High Temperature Phase (duration 6 hrs). The fuzes must be safe and operable after these tests. 6. Explosive Component Output Measure-
ment by Aluminum Dent Test 303 is briefly
described in Vol 4, pp D1092-R & D1093-L.
7. Explosive Component Output Measure-
ment by Steel Dent Test 301 is briefly de-
scribed in Vol 4, p D1093-L and its re-
vision Test 301.1 in Change Notice 1,
24 July 1967.
8. Extreme Temperature Storage Test 112
is briefly described in Vol 4, p D1093-L.
9. Field Parachute Drop Test 211 is
briefly described in Vol 4, pp D1093-L
& D1093-R.
10. Five-Foot Drop Test 111 is briefly
described in Vol 4, p D1093-R.
11. Forty-Foot Drop Test 103 is briefly
described in Vol 4, p D1093-R.
12. Fungus Resistance Test 110 is briefly
described in Vol 4, p D1094-L.
13. Impact Safe Distance (Projectile) Test
208 is briefly described in Vol 4, p D1094-L.
14. Jettison (Aircraft Safe Drop) (Fuzes)
Test 201 is briefly described in Vol 4, p
D1094-L, while its revision is given as
Test 201.1 in Change Notice 1 (24 July
1967).
15. Jettison (Aircraft Safe Drop) (Fuzes
System) Test 205 is briefly described in
Vol 4, p D1094-L & R.
16. Jettison Aircraft Safe Firing (Rocket
Type) Test 204 is briefly described in
Vol 4, p D1094-R.
17. Jettison (Simulated Aircraft Drop from
Ground Launcher) Test 203 is briefly de-
scribed in Vol 4, p D1094-R.
18. Jettison (Simulated Aircraft Safe Firing
from Ground Launcher) (Rocket Type) Test
202 is briefly described in Vol 4, pp
D1094-R & D1095-L, while its revision as
Test 202.1 is given in Change Notice 1,
19. Jolt Test 101 is briefly described in
Vol 4, p D1095-L, while its revision as
Test 101.1 is given in Notice 3 (11 June
1969).
20. Jumble Test 102 is briefly described in
Vol 4, p D1095-R, while its revision is
given as Test 102.1 in Notice 3 (11 June
1969).
21. Leak Detection Test 118 (Notice 4), de-
vised in 1971 was not described in Vol 4
of Encycl, published 2 years earlier. This
test is applied to live fuzes filled with
either halogen or helium to check the in-
tegrity for leaks that may affect safety and
operability. Detailed description of equip-
ment and test is given on six pages but
with no illustrations.
21. Missile Pull-Off from Aircraft on Ar-
rested Landing (Ground Launcher Simulated)
Test 209 is briefly described in Vol 4, p
D1095-R.
22. Muzzle Impact Safety (Projectile) Test
207 is briefly described in Vol 4, p D1096-L.
24. Rain Test (Exposed Fuzes Storage) Test
109 is briefly described in Vol 4, p D1096-L.
25. Rough Handling (Packaged) Test 114
is briefly described in Vol 4, pp D1096-L
& R.
26. Salt Spray (Fog) Test 107 is briefly de-
scribed in Vol 4, pp D1096-R & D1097-L.
Its revision given as Test 107.1, entitled
Salt Fog is in Notice 6 (20 March 1972).
27. Sand and Dust Method 116 is briefly
described in Vol 4, p D1097-L. Its revision
is given in Change Notice 1 (24 July 1967).
See also Dust Test 116.1, Item 5 above.
28. Static Detonator Safety Test 115 is
briefly described in Vol 4, p D1097-L & R.
29. Temperature Humidity Test 105 is
briefly described in Vol 4, p D1097-R.
30. Thermal Shock Test 113 is briefly de-
scribed in Vol 4, p D1097-R.
31. Time-to-Air Burst (Projectile Time)
Test 210 is briefly described in Vol 4, p
D1098-L.
32. Transportation Vibration Test 104 is
briefly described in Vol 4, p D1098-L & R.
Its revision in Change Notice 1 (24 July
1967) supersedes MIL-STD-331, p 1 of 10,
January 1966 (8 pages).
33. Vacuum-Steam Pressure Test 106 is
briefly described in Vol 4, p D1098-R.
34. Waterproofness Test 108 is briefly
described in Vol 4, p D1098-R.
Besides the above tests there are about
90 tests for fuzes listed on pp D1098 to
D1103-L and also 45 refs are listed on pp
D1103-R to D1107-L of Vol 4 of this Encycl.
Fuzes, Physical Testing. Eighty-nine tests are either briefly described or listed in Vol 4 of Encycl, pp D1099-L to D1103-R. There are forty-nine refs listed on pp D1103-R to D1107-L.

Fuzes, Sources for Information. A paper entitled "Sources for Fuzes Information" was prep'd in 1972 by Gunther Cohn, Senior Staff Engineer, Franklin Institute, Research Laboratories, Philadelphia, Pa, 19103. The price is $2.50, incldg postage.

We are quoting its Abstract:

"The post-World War II information explosion has left its mark on fuzes documents as well. Now for the first time, here is a serious effort to bring together useful information in the field of fuzing. Containing 125 prime references with annotations and a score of sources, the paper has four categories:

1. the general information needed to find one's way thru the fuzes maze, including notes on fuzes categories and reference availability,
2. the basic references and agencies that serve as sources of fuzes information,
3. the document collections containing fuzes information, like standards, engineering design handbooks and document centers, and
4. references on specific topics of key interest."

Fuzes, Spitback. A fuzes located in a nose of a shaped-charge munition. When initiated by impact it produces a deton which is directed toward the base. The combination of Point Impact Fuzes and base element is referred to as a PIBD (Point Initiating Base Detonating) Fuzing System.

Ref: Glossary Ordn (1959, 128-R)

Fuzes Train, also known (when combined with a projectile charge) as "High-Explosive Train" or "Bursting Charge Explosive Train" Its definition is given in Vol 4 of Encycl, pp D837-R & D838 (See also Fig 1-21a on p D838-L & Fig 1-21b on p D839-L)

German Fuzes Train, known as Zündersatz consisted practically of the same elements as American Compositions of many of Ger Fuzes Trains were detd during WWII at PicArsn and the results taken from PATR 1555 (1945), pp 11-15 are listed in PATR 2510 (1958) in Table 17 on p Ger 65

FZG. Same as German "Flying Bomb" V-1 (Vergeltungswaffe Eins) - "Revenge Weapon One", which is described in PATR 2510 (1958), p Ger 213-L and illustrated on p 214.
"G" (Pólvora progresiva de fósil tipo "G"). A progressive rifle propellant manufactured after WWII at Asturias (Spain) by the Fábrica de Pólvoras y Explosivos. It consisted of NC 97.75, DPhA 0.75, Na oxalate 1.00, volatiles 0.40 and graphite 0.1% which, previous to coating the grains of propellant, were slurried in 2 to 4% alcoholic solution of Centralite or camphor. This coating served to moderate the initial combustion and to render the propellant progressive burning. Na oxalate served as a muzzle flash reducer and DPhA as a stabilizer. The grains were in the form of squares 1.20 to 1.50mm across and 0.25 to 0.35mm thick.

Ref: Vivas, Feigenspan & Ladreda, Vol 3 (1948), 225

"G" (Pulver). See under Cool Propellants in Vol 3 of Encycl, p C511-R and also under Gallwitz in Vol 5, p E116-L

"G1" (Pulver). Old Austrian Black Powder used in cannons. Type a (grains 7mm) was used in 80 x 90mm cannons, while Type b (grains 13mm) in cannons 120 & 150mm.

Ref: Daniel (1902), 322

"G3" (Fusehead). See Fusehead "G3"

"C-117-b" (Rocket Powder). A double-base solventless extruded propellant consisting of NC 50.0, NG 30.0, DNT 14.5, Ethyl Centratlite 4.0% & K sulfate 1.5% with carbon black 0.02 & Pb stearate 0.40 added. This propellant is smokeless, but has a high heat of expln which may give nozzle & trap erosion.


GA. Chemical Warfare Agent belonging to the group of nerve gases, known as G-series. It is one of the G-Agents. Its formula and brief description are given in Vol 2 of Encycl, p C167-R. It was first prep'd during WWII in Germany by treating the dichloride of dimethylaminophosphoric acid (an irritating agent, known as Product 39) with Na cyanide, ethanol and chlorobenzene. It was known as Tobun or Trilon 83. It was used mixed in bombs and rockets with 20% chlorobenzene serving as a stabilizer, under the name Tobun B.

In Glossary of Ordn (1959), p 130-L, GA is called Ethylphosphorodimethylamidocyanide (See also under G-Agent)


Ref: Anon, MAF 26, 497–501 (1952) (Obituary)

Goson. Same as Grenadine


Godolinium, Gd. Rare-earth element having atomic No 64 & atomic wt 157.26; lustrous metal, sp gr 7.87; mp 1350° (Lange), 1325° (Ref 2); bp 2725° (approx); sol in dil acids, reacts slowly with w. Exhibits a high degree of magnetism, especially at low temp. Was first obtd in 1880 by Marignac from gadolinite.
which is a natural silicate of beryllium, iron and yttrium with rare-earth metals. Crystalline comds of Gd, especially, Gd_2(SO_4)_3·8H_2O are used in magnetic method of obtg extremely low temps. Gd has high thermal neutron capture cross-section and is used as an alloy in stainless steel for nuclear control. Some of its salts, as well as those of germanium and gold, were patented by Dement in smoke producing comds (Ref 3).


Gadolinium Oxide, Gd_2O_3, mw 362.52; wh to cream-colored powder, sp gr 7.407 at 15/4°, mp 2330°; hygroscopic and absorbing CO_2 from the air; insol in w; sol in acids except HF. Used in nuclear reactor control rods, neutron shields, catalysts, dielectric ceramics, filament coatings, special glasses and as P activator.


Gaens Explosive, patented in 1889 in Germany, was prep'd by mixing collodion cotton (gelatinized by ethyl acetate) with saltpeter and Aman ulmate. The latter compd is the salt of umlic(or geic)acid, C_20H_44O_9, which was obtd from peat, previously washed with a soln of Na carbonate.

Refs: 1) Daniel (1902), 322 2) Hackh's Dict (1944), 878-L

"GAF" Carbonyl Iron Powders. Trademark of General Aniline and Film Corp., 435 Hudson St, New York, 10014, for microscopic almost perfect spheres of very pure iron (99.6-99.9% Fe). They are produced in eleven carefully controlled grades ranging in particle size from 3 to 20 microns in diam. Used in high frequency cores for radio, telephone, television, short wave transmitters, radar receivers and direction finders. Also used as alloying agents, catalysts, in powder metallurgy and in magnetic fluids.

Ref: CondChemDict (1961), 524-R

G-Agent. Any of a group of war gases, known as nerve gases. This group is called G-Series (Ref 2).

The following nerve gases are described in Vol 2 of Encycl (Ref 3), under CHEMICAL AGENTS: GA or Tabun (p C167-R); GB or Sarin (p C167-R); GD or Soman (p C168-L) and GF (p C168-L).

More detailed description is given for three of the above, originally German, gases in PATR 2510 (Ref 1), under Trilons on p Ger 204-L: Tabun (Trilon 83, T83 or T100); Sarin (Trilon 46, T46 or T114) and Soman (Trilon 7).


GAGES (Brit GAUGES). There are several meanings for the term "gage", which include:

Gage Measures (such as "wire gage", "sheet metal gage", "firearms gage", etc) and Instruments for/or Means of Measuring or Testing, (such as "Bichel Gage", "Copper Crusher Gage", "Diaphragm Gage", "Piezo-electric Gage", "Strain Gage", etc) Gage of Firearms. In case of a shotgun, the gage is expressed as the number of lead balls of the diameter of the bore required to weigh 1 lb. Thus a 12 gage shotgun has a bore diameter of 0.729 inch because 12 lead balls of 0.729 inch diam weigh 1 lb.

The measurements of shotguns of current sizes are standardized on the above basis as follows: 8 gage=0.833 inch; 10 gage=0.775, 12 gage=0.729, 14 gage=0.693, 16 gage=0.662 and 20 gage=0.615 inch (Ref 1, p 64 & Ref 2, p 131).

The following gauges for measuring pressure developed by expts and propmts are described in Vol 3 of Encyclopedia (Ref 3): Bichel Pressure Gage or Bichel Closed Bomb (pp C331-R & C332-L)
British Service Closed Vessel Gauge (pp C333-R & C334-L)
British Service Crusher Gauge (p C336)
British Strain Gauge (p C341)
Burlot-Malsallez Gage (French)(p C332)
CSE (Commission des Substances Explosives) Closed Bomb Gage (French)(p C332-R)
Dolgou Bomb Gage (Russian). Similar to Bichel Bomb but arranged vertically (p C331-R)
Fluid Pressure Cell SR-4 of Baldwin (US)
(p C342-R)
German Closed Bomb Gages (p C333-R)
Kistler Quartz Pressure Transducer (US)
(p C342-R)
Optical Spring Gauge. See Petavel Manometer
Petavel Manometer (British) (p C337-R)
Piezoelectric Gage (Quartz) (US) (p C339-R)
Piezoelectric Gage (Tourmaline) (US) (p C340-R)
Sarrau-Vieille Closed Bomb Gage (French)
(p C333-L)
Spring or Mechanical Gages (British), which include Petavel Manometer (See above) and
High-Pressure Spring Gauge (p C338)
US Closed Vessel Gages. One of them, presented in Fig on p C334, is described on p C335. The so-called External Crusher Gage T14 is shown in Fig on p C336-L, while the Internal Crusher Gage M11 is in Fig on p C337-L

US Strain Resistance Wire Transducer Pressure Gage. Model C-AN is described on p C342 and illustrated in Fig on p C341-R
Vieille Type Bombs (French) are mentioned on pp C331-R & C332-L

Gages, Crusher. See above under GAGES

Gages, Diaphragm. See Fig G1. The gage is placed a fixed distance from the expl to be tested and the deflection of the steel or copper plate disc is measured. Because of the complex nature of the response the gage is useful only for comparison purposes

Gages, Optical Spring. See above, under GAGES

Gages, Piezoelectric. See above, under GAGES

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Fig G1 Construction of UERL diaphragm gauge.
Gages, Spring. See above, under GAGES.

Gages, Strain. The fundamental idea of a strain gage is that stretching or compressing a length of wire will change its resistance. The length of wire on stretching increases, while at the same time the diameter decreases, and since resistance varies directly as the length and inversely as the diameter, these two effects act to increase the resistance. Then, if such a wire is properly attached to a member which is to be stressed, then the resulting deformation (strain) will be transmitted to the wire changing its resistance. Knowing the character of the stress and the dimensions and material of the stressed member, the change in gage resistance can be related to the dimensional change or strain in the stressed member. Fig G2 shows the construction of a typical size SR-4 strain gage made by Baldwin Lima Hamilton Corp.

In addition to changes in dimension of the gage wire, there is also a change in metal properties of the wire. In an alloy known as Advance (58% Cu, 45% Ni) a change in length of 0.1% causes a change in resistance of about 0.2%. The ratio of percent resistance change to percent length change is known as the "gage factor". Gage wire is usually 0.001 inch in diameter, except in certain types, is embedded in a suitable cement and mounted on a thin piece of paper. To use a gage as shown in Fig G2, it is attached in the desired spot on the stressed member with nitrocellulose cement (Duco cement, Baldwin SR-4, or equal). The cement penetrates the paper mounting and forms a bond between the wires and the test object. The gage and the cement thus undergo the same tensile or compressive stress as the member they are attached to. When there are stresses acting in more than one direction, a special type of gage is used as shown in Fig G3. These gages are called rosettes. Gages can be operated with nitrocellulose cement up to 180°F. The wires are embedded in Bakelite plastic and applied with a Bakelite cement for use from 180°F to 400°F. Above 400°F ceramic cement is used. Fig G4 is a special type of unbonded gage which is used between a fixed frame and a movable armature.

![Gage Construction Diagram](image)

**FIG G2** Construction of a typical size of SR-4 bonded strain gage

![Gage Diagram](image)

**FIG G4** Simple form of unbonded strain gage developed by Statham Laboratories

![Gage Diagram](image)

**FIG G3** Three designs of bonded rosettes used where stresses are multi-directional
Elementary strain gage circuits are shown in Fig G5. The first circuit [Fig G5(A)] is probably the most simple that may be used with a strain gage. For this circuit the signal voltage may be represented by:

\[ V_s = V_b \left( \frac{R + \Delta R}{R + R_1 + \Delta R} - \frac{R}{R + R_1} \right) \]

where: 
- \( V_b \) = signal voltage due to the strain, volt
- \( V_s \) = battery voltage, volt
- \( R_1 \) = ballast resistor, ohm
- \( R \) = Strain gage resistance when relaxed, ohm
- \( \Delta R \) = change in strain gage resistance due to strain, ohm

The two terms in the parentheses of this equation represent the potential in the unstrained condition (the right term) and in the strained condition (the left term). By setting the value of the ballast resistor \( R_1 \) equal to the strain gage resistance \( R \), a process that is often used in practice, the equation for the signal voltage becomes:

\[ V_s = \frac{\varepsilon F_g V_b}{2(2 + F_g)} \]

where: 
- \( F_g \) = gage factor, dimensionless
- \( \varepsilon \) = strain, in/in

The simple bridge circuit [Fig G5(B)] effectively eliminates the DC component of signal that was present in the ballast circuit. Except for the limitation of the DC component, the magnitude of the signal voltage is identical to that of the ballast circuit provided the resistances \( R, R_1, R_2 \) and \( R_3 \) are equal. The battery voltage is usually 3 to 6 volts. A typical commercial application is shown in Fig G6 in which gages on loading screws show pressure between calendar rolls.

Besides strain measurement, strain gages are used in measurement and control, Load cells are prefabricated transducers and are increasingly used because the strain gages are already mounted. One application of a load cell is the rapid weighing of heavy equipment with infinitesimal motion.

In military applications, strain gages are used to measure pressure in rifles and gun tubes, pyrotechnic ejection systems, gas generators and propulsion systems. See also US Strain Resistance Wire Transducer Pressure Gage under GAGES and in Vol 3 of Encycl, pp C341-R and C342


![FIG G6 Strain gages on loading screws show pressure between calendar rolls](image-url)
Gain Rifling, Gain Twist, Gaining Twist, Progressive Rifling or Increasing Twist of Rifling (Ger names: Zunehmender oder Wachsender Drall). Rifling in which the degree of twist (num) increases from the origin of rifling to the muzzle.

Under the term of rifling are known helical grooves cut in the boc of a rifled gun tube beginning at the front face of the gun chamber (origin of rifling) and extending to the muzzle. The purpose of rifling is to impart spin and stability to the projectile, so that it will travel nose first to the target. Engagement of projectiles greater than about .60 inch in diam with the rifling is generally accomplished by use of a rotating band, also known as driving band (See in Vol 5 of this Encycl).

Accdg to Mr R.P. Baumann of PicArsn, Germans used during WWII progressive rifling in at least 13 of their guns. They are listed in Ref 2, p Ger 138-R.

Some Amer weapons using "gain rifling" are listed by Mathews (Ref 1).


Gain (Sheath). A Brit term for a metallic cup (sheath) attached to the bottom of the fuze. When filled with a comparatively sensitive HE (such as Tetryl), then connected to a detonator and inserted into a cavity in the main expl charge of a projectile (known as burster), it performs the same function as a booster, described in Vol 2 of Encycl (Ref 3, pp B243 to B246-L).

The idea of separating, by a metallic sheath, the bursting charge of a projectile from the booster belongs to Sir R. Robertson and dates to the time of WWI. It was done in order to eliminate the possibility of premature expls caused by set-back. In its original form, the device was intended to detonate an insensitive expl such as Amatol. It consisted of a strong steel tube, 3 inches long and 3/4 inch thick, screwed into the mouth of the shell and closed at the lower end with a plate strong enough to withstand the shock produced by a set-back and weak enough to be blown out by the expl wave of the booster. At the top of the tube there was a pellet of Black Powder with an axial perforation, which was ignited by the flash from the fuze screwed in over the gain. The flash from Black Powder was passed to an open capsule containing Mercury Fulminate situated immediately over two pellets of Tetryl located in the gain. The gain was placed in the long cavity, located in a cylinder of cast TNT imbedded in Amatol, which was the main charge in the upper part of the shell. The bottom of the TNT cavity contained a bag filled with crystals of TNT. The Fulminate detonated the Tetryl pellets from which the detong wave passed thru the TNT crystals to the cast TNT and so on, with increasing velocity to the main charge of Amatol (Ref 1, pp 162–63)

Fig G7 Gaine No 13
under "Aldonic Acids, Their Derivatives and Nitric Esters"

d-Galactose and Derivatives

d-Galactose or Hexose, \( \text{C}_6\text{H}_{12}\text{O}_5\cdot\text{CHO} \); mw 180.16; wh prismatic crystls, mp 165.5° (for anhydrous) or 118–120° for its monohydrate; soly of anhydrous compd in w is 10.3% at 0°C and 68.3% at 25°C; soly in alc = 0.6% at 38.5° in 85% alc; sol in pyridine; sl sol in glycerine. Can be derived from milk sugar by hydrolysis caused either by fermentation or by mineral acids.

On being nitrated it gives expl Pentanites, alpha and beta


d-Galactose Pentanitrate, \( \text{C}_6\text{H}_{12}\text{O}(\text{ONO}_2)_5 \); mw 405.14, OB +2.0%, N 17.29% (theory); N 17.18% (found). Nitration of d-galactose by slowly adding concd sulfuric acid to a soln of d-galactose in concd nitric acid (as indicated inRefs 1 & 2) produced (after cryst from alc) colorless, transparent adls which melted at 115–116° and exploded above 126°. They were insol in w and sl sol in alc and reduced Fehling’s soln slowly on warming. This compd was designated as alpha-Galactose Pentanitrate. The beta-Galactose Pentanitrate was obt by evaporating alc mother liquor of alpha compd. It was in the form of transparent monoclinic adls, melting at 72° and decompg at 125°. They were insol in w and v sol in alc; reduced Fehling’s soln and decompd slowly when stored at 50°C (Ref 3)

Refs: 1) Beil I, 915  2) W. Will & F. Lenze, Ber 31, 74-5 (1898)  3) Davis (1943), 243

Galcit (Abbr for Guggenheim Aeronautical Laboratory, California Institute of Technology). A brief description was given in Vol 1 of Encycl, p A497-R under Asphalt-Perchlorate Castable Propellants. The following may be added:

Galcits were heterogeneous mixts contg ca 25% of asphalt oil fuels and ca 75% of perchlorate oxidizers. Their specific impulse (\( I_{sp} \)) was ca 185 secs vs 200 for Ballistite


Galena (Galenite or Lead Glance), PbS, mw 239.28; gr cubic crystls, sp gr 7.5, hardness 2.5, mp 1120°; insol in w & alkalies; sol in concd nitric acid and in hot hydrochloric. Occurs in many US States, Canada, So America, Africa, etc. Serves as a chief ore of lead


Galeries d’essais. French Testing Galeries are briefly described in Vol 3 of Encycl, p C371, item D, under "Coal Mining Explosives, Testing for Permissability"

Galette. French for Cake, such as used during manuf of proplnts. It is described on p C3 in Vol 2 of Encycl

Slightly different information was given by US Army Attache Report of May 13, 1954, namely:

Galette 1–SD: NC 70.25–71.00 & NG 29.75–29.00% with water less than 1%  
Galette 2–SD: NC 73.06 & NG 26.94% with water less than 1%  
Note: SD stands for "sans dissolvant", which means "solventless"

Galex. Tradename of G & A Laboratories, Inc, Box 1217, Savannah, Georgia. and of National Rosin Oil Products, Inc, 1270 Ave of the Americas, NY 10020 for a stable non-oxidizing resin consisting principally of dehydroabietic acid; lt amber solid, sp gr 1.082 at 20/4°, softening p (B&R Method) 66°, fl p (Cleveland open cup) 210°C, fire
British gainses of WWII are described in Refs 2, which used to be confidential, and were not discussed by us earlier.

The term gainse was also applied to Japanese boosters and two of such Army devices are illustrated in Figs on p B246 of Ref 3.

British Fuze No 700 Mk II employs Gaine No 13, shown in Fig G7, for a rocket nose fuze. Explot of the gunpowder chge in the base of the fuze initiates the gaine which is located in the adapter ring below the fuze. The Nose Fuze No 731 Mk I also employs a gaine (not shown) used in rockets.


Gaine-relais. Fr for Adapter-Booster.


d-Galacton and Derivatives

Galactan, Gelose, Galactosan or Carraghan Moss, \((C_6H_{10}O_5)_n\); mw (162.14)_x; white carbohydrate, giving on hydrolysis galactose, \(C_6H_{12}O_6\).

A method of prepns from pectin matter of seeds of white lupine was described by Hirst et al (Ref 2). Vinogradova et al (Ref 3) prepd snow-white powder from same source contg 94.5% galactan, the rest being pentosan and uronic acids. Can also be obtd from agar-agar. Yields mucic acid on oxi-
dation. Its aqueous solns were used by the Germans in some AN expls for controlling plasticity, such as in Wetter-Wasagit B, which contd: NG 27.8, NC 0.7, AN 30.5, NaCl 39.5, gelose 0.7, woodmeal 0.3 & talc 0.5% (Ref 4).


d-Galactan Trinitrate or Galactosan Trinitrate, \([C_6H_{10}O_5(ONO_2)]_n\); mw (297.14)_x, N 14.14%, OB to CO\(_2\) –24.2%; white cryspts, sl sol in acet. Accdg to Davis (Ref 2), it was obtd by the action (during several days) of mixed nitric-sulfuric acid on d-galactose and then deposited from alcohol in crusts of small cryspts. Vinogradova et al (Ref 3) prepd it by nitrating galactan of 94.5% purity; the resulting product contg 14.03% nitrogen, approx corresponded to Galactan Trinitrate. Nitration was conducted by means of an anhydrous mixture of nitric acid 45, phosphoric acid 45 and phosphoric anhydride 10% at 0°C.

It was an expl which was unstable, probably due to the fact that it was not pure. Its sensitivity to impact was comparable to that of Tetryl and its brisance and power were slightly lower than of TNT.


d-Galactonamide and Its Penta-nitrate are briefly described on pp A122-R & A123-L in Vol 1 of Encycl, under “Aldonic Acids, Their Derivatives and Nitric Esters”

d-Galactonic Acid and Its Penta-nitrate are briefly described on pp A122-R & A123-L in Vol 1 of Encycl, under “Aldonic Acids, Their Derivatives and Nitric Esters”

d-Galactonic Acid Penta-nitrate, Methyl Ester or Methyl-d-galactonate Penta-nitrate is briefly described on p A123-L in Vol 1,
p (Cleveland open cup) 240°; sol in ordinary organ solvents, waxes and compatible with SR-S, Neoprene, rubber and many resins. Used for rubber-based pressure sensitive adhesives and for many other purposes which are indicated in Ref.

Ref: CondChemDict (1961), 525-L

Gallacetophenone Azide or Azidogallacetophenone (Azido-2,3,4-tri-xy-acetophenone, in Ger), C₈H₉(N₃)COCH₂N₃; mw 209.16, N 20.10%, plates (xylene), mp 155°. Prepd by treating the w-chloro compd with NaN₃ in hot water

Refs: 1) Beil 8, (686) 2) G. Barger & A.J. Ewins, JCS 97, 2260 (1910) & CA 5, 1083 (1911)

Gallorher Powder. A modification of BkPdr contg, besides salt peter, carbon & sulfur, the sulfates of Fe & Cu and pulverized tan bark. It was patented in the US by Lloyd & Walker.

Ref: Daniel, Dicte (1902), 322


Gally Practice Ammunition. Small Arms ammunition with a reduced charge used in gallery practice and also for guard purposes.

Ref: Glossary of Ordn (1959), p 133-L

Gallic Acid or 3,4,5-Trihydroxybenzoic Acid, (HO)₃C₆H₂CO₂H.H₂O; mw 188.13; colorless or sl yel ndls or prisms; sp gr 1.694 at 4/4°, mp loses water at 100°, decmp at 235°, sol in w or edh; sol in alc or in glycerin.

Can be obtd by the action of mold on solns of tannin (gallotannic acid) or by boiling the latter with strong acid or caustic soda. Used as a reagent for detecting small amts of ferric salts and acids; also in manuf of inks, pyrogallol. Davis (Ref 2) describes its use in mixtures with KClO₃ in Non-Picrate Whistlers.

Its US specification requirements and tests are in Ref 5
Refs: 1) Beil 10, 470, (236) & (335)  
2) Davis (1943), p 73 (Use in fireworks)  
3) Hackh’s Dict (1944), 365-R  
5) US Specification MIL-A-13601(Ord)(Cancelled and not in files of Picatinny Arsenal)

Gallic Powder, patented in 1869 by Horsley, England, contd K chlorate 75 & galls or nutgalls (noix de galle) 25%  
Ref: Daniel (1902), p 322

Gallium (Ga) or Austrium, Ga, atomic wt 69.72, atomic No 31; silvery-wh metal, sp gr 5.885 at 24°, mp 29.7°; bp 1600°(Ref 2), 2535°(Lange); insol in w; sol in acids & alkali; sl sol in Hg. Obt’d from bauxite and Zn ores. Has been suggested for use as a backing material for optical mirrors and as a possible heat exchange medium in nuclear power reactors  
Refs: 1) Hackh’s Dict (1944), 365-R  
2) CondChemDict (1961), 525-R

Gallium Trioxide, Ga(N₃)₃. See Vol 1 of Encycl, p A536-L

Gallotannic or Tannic Acid (Digallic Acid or Tannin), (HO)₃C₆H₄-CO₂-C₆H₄(OH₂-CO₂H; mw 322.22, sl yel amor powder, mp decompd 200–210°; sol in w, alc & ater; almost insol in eth, benz, chl & petr edh. Naturally occurring, probably as a glucoside, in gall-nuts (nutgalls) and in tree barks (such as sumac, oak & hemlock). Used for tanning skins, prepn of chemicals (such as gallic acid, pyrogallic acid and hydrosols of noble metals). Also used as a component of some exps such as French Poudre de mine de sûrèf, described in Daniel, Dict (1902), p 761 and for treatment of skin bums  
Refs: 1) Hackh’s Dict (1944), 829-R(Gallotannic Acid)  
2) CondChemDict (1961), 1105

Galls (Nutgalls, Aleppogalls, or Turkey galls). Excesses on various kinds of oak trees resulting from the deposition of insect eggs. The best grades (55–60% gallochastic acid) come from Iran, Syria, Turkey and Tripoli; the poorer grades from Italy, France, Germany and Austria. Galls come in powders of colors ranging from black thru green to white, owing to degrees of maturity; the darker being more mature and contg more gallochastic acid. Serves as source of gallic & gallochastic acid, manuf of inks and as a component of some older types of expls, such as Gallic Powder (qv)  
Ref: CondChemDict (1961), 525-R & 526-L

Gallwitz, Uto (? –1943). Ger General, one of the most prominent ordnance specialists. He introduced before WWII the low calorific value propellants (such as "G" Pulver) by substituting DEGN & TEGDN for NG. He also introduced NGu (Nitroguanidine) as a cooling agent and this propellant became known as Gudolpulver. Gen Gallwitz was killed during WWII at the Russian Front.

His work on the development of cool propellants is described in the book: Uto Gallwitz. "Die Geschützladung" (Heereswaffenamt, Berlin (1944), which was classified during WWII in Germany as "secrete")

See also Cool(Cooled) Propellants in Vol 3 of Encycl, p C511-C512-L

Galvoni, Luigi (1737–1798). An Italian physician and anatomist who discovered the galvanic current in the course of working with frog muscles  
Refs: 1) Hackh’s Dict (1944), 366-R  
2) EncyclBrit 9(1964), p 1107

Galvonic (Voltaic). Pertaining to an electric current produced by chemical action  
Ref: Hackh’s Dict (1944), 366-R
Galvanism. A branch of physics which deals with electric currents produced by chemical action, as opposed to those produced by heat, friction or induction
Ref: Hackh’s Dict (1944), 366-R

Galvanize. To protect an easily oxidizable metal (such as iron) with a less oxidizable metal (such as tin or zinc) by electric means
Ref: Hackh’s Dict (1944), 366-R

Galvanograph. The photographic record of a sensitive galvanometer arranged so that the mirror deflects a beam of light onto a moving film or paper
Ref: Hackh’s Dict (1944), 366-R and Fig on p 367-L

Galvanometer. An instrument for detecting and measuring the strength of an electric current. It consists essentially of a magnetic needle suspended in a wire coil. The slightest deflection of the needle produced by a current thru the coil is measured by some optical system, eg reflection of a beam of light from a small mirror attached to the needle, and observation of the reflected beam on a scale. The coil may be fixed and the magnet movable or vice versa
Ref: Hackh’s Dict (1944), 366-R & 367-L

Galvanometer Chronograph was invented in 1849 by Pouillet and in 1851 by Helmholtz. It was improved by Hamburger (in 1885), Ramsauer (1903) and Timme (1921)
Ref: Cranz, Ballistik, Vol 3(1927), 101-07
Note: Other types of chronographs are described in Vol 3 of Encycl, pp C307-R to C311-R

Galvanometric Titration Method. As exemplified by the Karl Fischer Method, the KF Reagent is added in excess to the test solution, and the excess back titrated with aqueous methanol. If a pair of Pt electrodes be immersed in the soln, connected to a power source and a galvanometer, then the latter will show a current so long as any iodine (which is what is being back titrated) is left. See also under Karl Fischer Method on pp D1622-L to D1628-L in Vol 5 of Encycl

Gombir or Gambier (Pale Catecchu). An odorless brown powder prepd by drying an extract from a decoction of the leaves and twigs of an Indian shrub, Ourogyparia or Uncaria gambir. It is insol in w and sol in alc. Used as an astringent and tanning material
Ref: Hackh’s Dict (1944), 367-R
Note: Someone has reported that gambir was used in admixture with K chloride in some “safety explosives”

Gamma Cellulose. See Vol 2 of Encycl, under CELLULOSE AND DERIVATIVES, p C96-L. Alpha (α) and beta (β) cellulosics are described on the same page
More detailed description is given in Ott, Vol 2, pt 1 (1954), p 12

Gamma Radiation. The combined process of emission, transmission and absorption of gamma rays, as from the expln of atomic bomb
Ref: Glossary of Ordn (1959), 133-L

Gamma Radiation Effect on Explosives. Using Au-198 radiation the most affected were NG and PbN₃, while TNT and Pb stypheate were most stable. Binary expls such as Ballistite & Comp B, primers such as M26 also were studied (Ref 1)
The effects of gamma radiation on four selected fluoroeaxps:
MFTNB or PF 1-Monofluoro-2,4,6-trinitrobenzene or Picryl Fluoride
DFTNB 1,3-Difluoro-2,4,6-trinitrobenzene
TNTF 2,4,6-Trinitrobenzotri fluoride
TF-E Tetryl 2,4,6-Trinitrophenyl-β,β,β-trifluoroethyl nitramine

are reported by Avrami et al (Ref 2). Their behavior at different exposure levels is compared with the behavior of the parent compds, TNB & TNT; RDX & HMX are also included as controls. The determinations made on each expl were wt loss, vacuum stablility, mp, IR spectra, TGA, impact sensitivity, expln temp, and rate of detonation as a function of total gamma exposure. A brief description of the expln-containment irradiation capsule designed & used in these studies is also given.

Avrami et al (Ref 3) also subjected a group of eleven expl materials in powder & pellet form to Co 60 gamma radiation. Based on this work, a damage threshold as a function of total gamma dose was determined for each expl. The results indicate that the capability of the expls to withstand Co 60 gamma radiation decreases in the following order:
TACOT, TATB, DATB, HMX, Tetryl, TNB, TNT, RDX, PETN, NGU & BaN 6

Abbrns: DTA – Differential Thermal Analysis;
TACOT – Tetranitro-1,2,5,6-tetrazidibenzo-
cyclo-octatetraene; TATB – Triaminotrinitro-
benzene; TGA – Thermogravimetric Analysis;
DATB – Diaminotrinitrobenzene; NGU –
Nitroguanidine


Gamma Rays. Electromagnetic radiation similar to X-rays but of shorter wave lengths. Gamma rays originate in the nucleus of an atom, whereas X-rays originate in the extra-
nuclear structure. Gamma rays are emitted by radioactive substances (such as radium) as secondary radiation caused by beta (β) rays striking matter.

Note: Beta rays consist of a stream of negatively charged particles (electrons) emitted from radioactive substances with a velocity of light (186000 miles/sec or 2.99x10 10 cm/sec). There are also alpha rays, which consist of a stream of positively charged particles emitted from radioactive substances with a speed of 20,000 miles/sec (1.922x10 8 cm/sec).

Refs: 1) Hackh’s Dict (1944), 367-R
2) Glossary of Ordn (1959), 133-L

Gamma Rays, Analysis. The technique of making radiographs with γ-rays (Gamma Rays Analysis) is fundamentally similar to radiography with X-rays. It consists in placing the object to be examined (such as cast metal, ammunition, etc) between the source of gamma ray radiation (such as radium sulfate or mesothorium) and a photographic plate or film. Any cavity in the sample will be shown on the film (plate) as a dark region. Radiographs made with γ-rays are called gamma- graphs. This technique is easier to apply than X-ray technique and is less expensive.

The first γ-ray photographs were obtd in 1925 by Lipon & Laborde and this technique was adopted in 1928 in Russia. The work started in the US in 1929 at the Naval Ordnance Research Laboratory (Compare with Betatron, described in Vol 2 of Encycl, pp B108 & B109).

2) H.R. Grand et al, PhysRev 47, 782 (1935) (Gamma-ray from disintegration of beryllium by Deuterons and Protons)
3) K. Lask-Horowitz et al, PhysRev 48, 100 (1935) (Gamma rays from nitrogen bombarded with Deuterons)
4) R.G. Herb et al, PhysRev 51, 691–98 (1937) (Gamma rays from light
elements due to proton bombardment)
6) N.L. Mochen in ASTM "Symposium on Radiography", Philadelphia (1943), pp 48-64 and 163-75
7) A. St. John & H.R. Isenburger, "Industrial Radiography", J. Wiley, NY (1943) (Description of various methods of testing; included 1314 refs)
8) Addenda to "Industrial Radiography", by H.R. Isenburger, lithographed and copyrighted by St. John Laboratory, Caliform, New Jersey (1943) (Includes bibliography from 1942 to 1945, up to Ref 1699)
9) Ditto, Second Supplement includes bibliography from 1945 to 1948 up to Ref 2511
10) M. Hetényi, "Handbook of Experimental Stress Analysis", J. Wiley, NY (1950), p 982 (Fairly comprehensive description of γ-rays technique is given)
15) Damiaan de Soete, "Gamma Ray Spectrometry", Brussels, Paleis der Academien (1967)

More detailed description will be given under TOLUENE AND DERIVATIVES
Refs: 1) Clift & Fedoroff, Vol 1, Lefax, Inc (1942), Chap 5, pp 5 & 19
2) Urbaník 1 (1964), pp 41, 132, 208

Gamsits. Swiss nonpermissible expls, described in Vol 3 of Encycl, p C443-L, under COMMERCIAL OR INDUSTRIAL EXPLOSIVE. One of them known as Telsit-Gamsit cont 25% AN 60, NG 21, NGc 5, Collod Cotton 1.6, woodmeal 0.4 & liq DNT 12% (Vol 3, p C444-L)

Gap. Maximum distance at which a cartridge (stick) of an expl (such as Dynamite) would explode or detonate by influence (sympathetic deton) of another cartridge of the same or of different expl
Ref: Encycl of Exps, Vol 1 (1960), p XIV (Gap Test)

Gap Tests. Various tests are listed in Vol 4 of Encycl, pp 033-4 & 034-5 and also under DETONATION (AND EXPLOSION) BY INFLUENCE OR SYMPATHTIC DETONATION, where the following tests are described:
Air-Gap Test (p D397-R);
Booster-Gap Explosive Sensitivity Test of Cole & Edwards (p D398-L);
Card-Gap Sensitivity Test of Cook et al (p D396-R);
Card Test (p D399-L);
Four-Cartridge Test (p D399-L);
Shock-Pass-Heat-Filter (SPHF) Sensitivity Test (p D399-L & D399-R);
Three-Legged Table Sensitivity Test (p D399-R);
Whole-Cartridge Sensitivity Test (p D399-R) and the following gap tests are listed giving their location in Vols 1 and 3 of Encycl:
Booster Sensitivity Test (p D398-R);
Coefficient de self-excitation (p D399-L);
Halved Cartridge Gap Method (p D399-L);
Wax Gap Test (p D399-R)
Note: "Improved Gap Sensitivity Test for Permissible Explosives" was reported by

Gamma-Rays, Behavior of Propellants under was discussed by:
E. Piantanida & M. Piazzini in Chimica e l'Industria (Milano) 42, 1238-42 (1960) & CA 55, 20434 (1961)

Gamma-TNT or 2,4,5-Trinitrotoluene. Found to the extent of about 2.9% in manuf of 2,4,6-TNT, the principal isomer found in quantity 95.5%. Two other isomers: beta- (or 2,3,4) and zeta- (or 2,3,6) are found in quantities 1.3% and 0.3%, respectively. Gamma TNT consists of yel crys, sp gr 1.629 at 20/4°, mp 104° and bp - expl at 290-91°

Gamma-Dinitrobenzene. Found to the extent of about 2.3% in manuf of 2,4-DNB, the principal isomer found in quantity 97.7%.

Gamma-Nitrobenzene. Found to the extent of about 1.2% in manuf of 2,4-NB, the principal isomer found in quantity 98.8%.

Gap Test of Spencer Chemical Co., Kansas City, Missouri, was described as "Wax-Gap Test" in Vol 1 of Encycl., p A354, Note c, under AMMONIUM NITRATE BLASTING EXPLOSIVES. Following are some properties of Spencer Chemical Co. AN prill—expls obtd thru the courtesy of S.J. Porter in 1960:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density g/cc</th>
<th>Deton Vel m/sec</th>
<th>Wax Gap inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spencer Prill with 6% oil</td>
<td>0.90</td>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>Ditto, coated with 3% diatomaceous earth</td>
<td>0.87</td>
<td>2260</td>
<td>2</td>
</tr>
<tr>
<td>Ditto, coated with 0.5% diatomaceous earth</td>
<td>0.86</td>
<td>2110</td>
<td>2</td>
</tr>
<tr>
<td>Prills and oil mixt</td>
<td>0.92</td>
<td>2420</td>
<td>3</td>
</tr>
<tr>
<td>mixts made from prills mixed with 1.5% diatom earth</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


CAR. Abbr for Guided Aircraft Rocket.

Garand, John C (1888–1974). Inventor of the .30-caliber M1 rifle used in WWII. He began working on it at Springfield Armory in the early 1920's and in 1936 it was accepted by the Army, while the Marine Corps accepted it in 1940. Garand's other contributions included numerous tools and gauges, as well as two machine rifles and three semiautomatic rifles.

Ref: Anon, Obituary in Miami Herald, Sun, Feb 17, 1974, p 6-B

Garand Rifle. Popular name for the US rifle, caliber .30 M1 (After its designer, John C. Garand, formerly of Springfield Armory). It is replaced now by the M16.


Garcia (Explosivo). A Spanish blasting expl suitable for use in mines or quarries: K perchlorate 65, Na nitrate 5, Mn dioxide 1.3, sucrose 26, urotropine [hexamethylenetetramine, (CH₂)₆N₄] 1.4, iron filings 1.0 & sulfur 1.3%

Note: Total of 101% is as given in the parent
Ref: A.H. Garcia, USP 2215608 (1940) & CA 35, 898 (1941)

Gargouze (French). A propellant bag as used in separate-loading ammunition.


Ref: Anon, MAF 32, III to XXI (1958)

Garside, Buckley & Yates patented in 1860, 1861 & 1862, complex compns listed in Daniel (1902), p 369 as Harrison (Poudres). They were mixts of nitrates (or chlorates) with sugar, lycopodium, starch, charcoal, sulfur & K ferrocyanide.
Gas and Gas Laws. Gas is a vaporous or air-like state of matter, defined as a non-elastic fluid in which the molecules are in free movement, and their mean positions far apart. Gases are characterized by their tendency to expand indefinitely, to diffuse and mix readily with other gases, to have definite relations of volume, temperature and pressure and to condense or liquify at low temperatures or high pressures. One gram-molecule of any gas contains under standard conditions (6.022 ± 0.006) x 10^23 molecules. This is known as Avogadro Number N, because it was defined by Amadeo Avogadro (1776-1856), an Italian chemist and physicist who formulated the gas laws (Ref 1, p 89-R)

A "perfect" gas is one which closely conforms to the simple "gas laws" of expansion, such as Boyle's Law, formulated in England by The Hon Robert Boyle (1627-1691) (Ref 1, p 141-R) and called in France Mariotte's Law, because it was formulated independently from Boyle by Edme Mariotte (1629-1684) (Ref 1, p 515-L). This law, called in Germany and Russia Boyle-Mariotte's Law, states that the product of volume and pressure is constant, pV = k, at constant temp. Another "gas law" states that the vol of a gas at 0°C increases with each °C by 1/273, provided the pressure is constant, and that the pressure increases with each °C, provided the volume remains constant. This law is known as Charles' Law, because it was formulated by French chemist Jacques Charles (1746-1822) (Ref 1, p 186-R). The so-called Dalton's Law, formulated by John Dalton (1766-1844), Engl chemist & physicist, founder of atomic theory, states that the pressure of a gas mixture equals the sum of the partial pressures of the constituent gases (Ref 1, p 252-R). The so-called Gay-Lussac's Law states that when gases interact, the volumes of the reacting gases and the volume of the reaction product are in simple proportions and can be expressed by whole numbers. This law was formulated by a French chemist and physicist Gay-Lussac (qv) Refs: 1) Hackh's Dict (1944), pp 89-R, 141-R, 156-R, 252-R, 368-R, 371-R & §15-L 2) CondChemDict (1961), 527-L & R 3) Kirk & Othmer (1970), pp 199-205

Gas Analysis or Gasometric Analysis. The methods of gas analysis may be subdivided into the following categories: 1) Volumetric and manometric methods; 2) Specific determinations; 3) Non-specific instrumental methods; and 4) Specific or semispecific instrumental methods (Ref 17)

Among the apparatus used in gas analysis, the following are most common: Allen, Burrell, Haldane, Orsat and Petersen

1649–1659 [Detailed description of a new type of gas analyzer suitable for 2, 3, and 4-component mixtures, such as CO₂, CO, H₂, and N₂ (or CH₄). Analysis is conducted automatically at any rate of flow gases. The apparatus consists of the arrangement shown in Fig. 8.]

Gas to be analyzed, containing CO₂, CO, H₂ and CH₄ (N₂) passes from a container thru U-tube (1) where moisture is absorbed by Ca chloride and then thru flowmeter (I) (called in Russian "tethemeter"), provided with a brass diaphragm (d₁) with diameter of opening ca 0.1–0.5mm. The difference between the pressure of gas before and after diaphragm is recorded (h₁) in mm of water. When the gas passes thru U-tube (2) filled with Ascarite, the CO₂ is absorbed and the remaining gases pass thru flowmeter (II) with diaphragm (d₂), where the difference of pressure (h₂) is measured. The next step is the passage thru cylinder (3) filled with CuO and heated to 290°C in order to oxidize CO to CO₂ and H₂ to H₂O. The resulting mixture passes thru U-tube (4) filled with Ca chloride where water is absorbed. Then the remaining mixt goes thru flowmeter (III) with diaphragm (d₃) to U-tube (5) filled with Ascarite to absorb CO₂ formed by oxidation of CO in cylinder (3). The remaining CH₄ (or N₂) goes thru flowmeter (IV) with diaphragm (d₄) and the height (h₄) is registered. Authors give equations allowing one to calculate the amounts of components, once h’s are known.

(Engl. translation of this paper is available at the Library of Picasinii Arsenal)


19) A. Schmidt, Explosivstoffe 1957, pp 1–7 (Apparatus for exact gas analysis)

Gas, Black. Same as Carbon Black, briefly described in Vol 2 of Encycl, p C55, under CARBON

Gas, Blast Furnace. It is a weakly combustible gas which passes out at the top of the blast furnace, such as used in recovery of iron from its ores. Compn of purified gas is given by Riegel (Ref), as follows: H₂ 1.0, N₂ 59.6, CO 26.0, CO₂ 13.4. Although its Btu is only 87 per cu foot, it is suitable for several purposes, such as to raise steam for the driving of the blowing engines, as internal gas fuel for the gas engine, driving the air compressor, to heat the stoves so that by means of the latter the incoming blast may be heated. If there is a surplus at the plant, the gas is piped to households of the employees.

Ref: Riegel, "Industrial Chemistry" (1942), pp 780–81
Gas, Blau. A fuel gas for airships obt by cracking gas oil at 550–600°. It is a mixture of propane, butane, pentane and hexane contg some hydrogen & methane in soln under pressure. The soln is handled in strong steel cylinders.


(The detonation of liq expls by gentle impact; the effect of minute gas spaces)

Gas Cannon Device, patented by Peake in 1934 (Ref), was claimed to be an improvement for previously proposed "gas cannons".
The object of this device was to provide a gas generating propellant in measured form. It consisted of pellets sol in water, coated with material, which although not readily attacked by moisture nevertheless dissolved when placed in a generating chamber in contact with a sufficient am of water. In one of the varieties, (Fig G9) the material was in the form of carbide stick (4) consisting of several sections. The "inlet port" (2) of the "generating chamber" (1) was closed by means of "cover" (3), which was pivoted and adapted to swing over, or away from the port (2). For loading the chamber (1), the cover (3) was removed and the carbide stick (4) inserted. Its sections were broken from the stick by means of a twist or bent and, after placing them in chamber (1), the cover (3) was placed over inlet port (2), so that no gas could escape from (1). When water was introduced in chamber, the protective coating of carbide sections was dissolved and the carbide reacted with water forming acetylene. As soon as all carbide dissolved, the striking mechanism (5) was to act on a primer, in order to explode the mixture of acetylene and air. Then the pressure of exploding gases escaping thru opening (6) propelled ball (7).

Instead of carbide stick, spaced, coated carbide balls could be used
Ref:  E.S. Peake, USP 1970017 (1934) & CA 28, 6314 (1934)

Gas Cannons. The first cannons were small, crudely made cast metal pots shaped like a vase which fired iron darts. The invention of gun powder about the middle of the 13th century made possible the use of cannon to throw projectiles by use of expanding gas.
In the first cannons, the propellant was ignited by thrusting red hot iron bars or spikes in the charge thru an aperture. Those that more nearly resemble the cannon of a later period were made of wooden staves fitted together, barrel-like and held tight with many folds of wet rawhide. Later when the use of iron became known the same construction was followed, square bars of iron being placed lengthwise and held together with iron hoops put on hot


Gas, Carbon Monoxide. A combustible gas described in Vol 2 of Encycl, p C62-L

Gas, Carburetted Water. See under Gas, Water

Gas, Chemical Warfare (CWG). See Vol 2 of Encycl, under CHEMICAL AGENTS OR CHEMICAL WARFARE AGENTS, pp C165-R to C171-R

Gas Chromatography and Gas-Liquid Chromatography. See Vol 3 of Encycl, p C293-R, under CHROMATOGRAPHY.

Gas Cleaning and Purification. Gas cleaning means the removal of impurities existing in the form of suspended liquid or solid particles, such as vapors, mist, fog, smog, smoke or dust. The impurities might also include gaseous substances that are objectionable or obnoxious, and their removal is usually called purification.

Gas cleaning may be accomplished either by mechanical methods (such as gravitational settling, centrifugal separation, filtration, ultrasonic precipitators, spray towers, mechanical scrubbers, etc) or by electrical methods (such as electrostatic precipitation by Cottrell Method, etc).


Gas and Coal Dust Explosion. Title of a series of papers published by K. Matsumoto in JMiningInstJapan 68, 260-5 & 379-82 (1952) & CA 48, 3691 (1954). The papers include adsortion of mine gases by the coal dusts; heat of adsorption of mine gases by coal dusts and ignition temperature of the coal dusts.

Gas, Coal. Accdg to Riegel (Ref), coal gas is a combustible gas obtd by distilling bituminous coal in small horizontal and vertical retorts. The primary object of distillation of coal is gas. As coal gas is high in illuminants (benzene and ethylene), it can serve as illuminating gas.

(See also under "Coal Processing for Obtaining More Valuable Products", in Vol 3 of Encycl, p C379-L)

Ref: E.R. Riegel, "Industrial Chemistry", Reinhold, NY (1942), p 153-54 (Retort for distillation of coal); pp 270-71 (Combustible and illuminating gas)

Gas, Coal Mine or Firedamp. A mixture of methane (CH₄) and air, usually present in "gaseous (fiery) coal mines", such as soft (bituminous) coal mines.

Explns of firedamp and its mixtures with coal dust are described in Vol 3 of Encycl, under "Coal Mine Explosions and Fires", pp C360-R to C367-R
Gas, Coke-Oven. It is a combustible gas obtained, accdg to Riegel (Ref), by distilling bituminous coal in larger retorts than those used in manuf of coal gas (See Gas, Coal). Both coke and gas are primary objects of manuf. Following typical compn of "straight coke-oven gas" is given by Riegel: CO₂ 1.8, C₅H₆0.9, C₂H₄ 2.3, O₂ 0.8, CO 5.5, H₂ 55.5, CH₄ 30.3, N₂ 9.2; total combustibles 88.2 and Buq per cu foot 555.

Gas, Combustible. Any gaseous substance or mixture consisting principally of carbon and hydrogen contg gases used for illuminating or heating purposes may be called combustible gas. These include blast furnace gas, carbon monoxide gas, coal gas, coke-oven gas, fuel gas, natural gas, oil gas, producer gas, tar gas, water gas and wood gas.

Gas Conditioning. Accdg to Riegel (Ref), gas conditioning means removing from a gas (usually air) suspended non-gaseous particles or droplets, as well as foreign gases and vapors, and adjusting its water-vapor content and temperature to predetermined levels.

Gas Dispersion. The dispersion of gas as bubbles in a liquid or in a solid (such as rubber, soap, plastic) is effected for one of the following purposes:
1) Agitation of liquid phases. It is produced by blowing the air or other gas (from a sparger etc) to the lower part of the container of liquid. This is usually done in cases when the containers are of such size or of such unsymmetrical shape as to make mechanical agitation ineffective or too expensive. Another case is when mechanical agitation is considered unsafe, as in the preparation of some expls. For instance, in the nitration of glycerin, air agitation is still used in some European countries.
2) Foam or froth production. This is done for other purposes than agitation. For instance, in the case of the flotation method of ore concentration, frothing causes the mineral particles of ore to float on the surface of the water. In some models of fire extinguishers, foam is produced by the action of carbon dioxide (evolved by the action of sulfuric acid on soda ash) in order to increase the volume of water in the extinguisher and to introduce bubbles of gas, which does not support combustion. In the case of solids such as soap, foam is produced to make the soap lighter so that it can float on the surface of water. In the case of plastics, air is introduced to decrease the specific gravity of the material; in the case of ice cream, to get more product per unit weight.
3) Gas-liquid contacting to promote absorption, or stripping. This is usually accomplished by bubbling the gas thru a liquid in the same manner as for agitation.
Refs: 1) S. Berkman & G. Egloff, "Emulsions and Foams", Reinhold, NY (1941) 2) J.H.

Gasdruckpatronen. See Gas Pressure Cartridges (Ger)

Gas Engines or Internal Combustion Engines. A prime mover, the fuel of which is burned within the engine. Examples are gasoline piston engines in passenger automobiles, outboard engines for motor boats, small units for lawn mowers, also diesel engines for trucks, tractors etc. Characteristic features common to all commercially successful internal combustion engines include 1) compression of air; 2) the raising of air temperature by the combustion of fuel in this air at its elevated pressure; 3) extraction of work from the heated air by expansion to the initial pressure and 4) exhaust


Gaseous Discharge Lamps. Gaseous discharge lamps consist of an electrically operated source of radiant energy characterized by the emission of radiation from a stream of ionized gas carrying current between electrodes in the lamp (See Fig G10). Lamps in common use include fluorescent, mercury-vapor and neon lamps. In general, gaseous discharge lamps provide their characteristic energy at higher efficiencies than other sources. All types of gaseous discharge lamps possess a negative resistance characteristic; that is, the resistance in the lamp envelope decreases with an increase in current. To prevent lamp failure from rapid rise of current, a current limiting element, or ballast, is used usually external to gas discharge envelope


Gaseous Detonations and Explosions. See in Vol 4 of Encycl: "Detonation (and Explosion) in Gases", pp D351–360; also "Detonation (and Deflagration) in Gases; Determination of Ignition Points", p D360 and "Detonation (and Explosion) of Gases, Vapors and Dusts"; "Development (Transition) from Burning (Combustion) or Deflagration", pp D360-R to D363-R

Addn Refs: A) S.G. Lipsett, CanadChem-ProcessInds 30 (3), pp 41–6 & 48 (1946); CA 40, 3265 (1946) (Gaseous and dust explns are discussed from the point of view of safety in the home and in the factory)
B) Ya.B. Zel’dovich & N.N. Simonov, Zhur-FizKhim 23, 1361–74 (1949); CA 44, 2753

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**FIG G10** Gaseous discharge tube in series with a DC voltage $V_2$ and a resistor $R$. The voltage $V_1$ serves to heat the cathode.
Gaseous Metal Treatment. In order to protect ordinary iron and steel items from rusting, they were coated, in Germany, by the diffusion of chromous chloride vapor at high temperature. The method was briefly described in Ref 1 and listed in Ref 2. 
Refs: 1) BIOS Final Repts 839(1946) & 1534(1946) 2) PATR 2510(1958), p Ger 63-R

Gaseous Mines or Fiery Mines. Under this term are known coal mines contg a mixture of firedamp (impure methane) and air in such proportions that a flame or spark would result in spontaneous explns. Mixts contg 5 to 12% of firedamp are usually considered expl, and the presence of coal dust in such mixts makes them more dangerous. The most dangerous is the mixt contg 9.5% methane. Only "permissible expls" are allowed to be used in gaseous mines. 
Ref: PATR 2700, Vol 3 (1966), pp C361 & C369

Gases, Detonation (and Deflagration) in. 
See Vol 4 of Encycl, p D360

Gases, Detonation (and Explosion) in. See Vol 4 of Encycl, pp D351 to D360

Gases, Dusts and Vapors, Detonation (and Explosion) of. See Detonation (and Explosion) of Gases, Vapors and Dusts in Vol 4 of Encycl, pp D350-R to D363-R

Gases, Fuel. Any combustible gas that furnishes heat on combustion, such as coal gas, natural gas or water gas. 
Ref: Hackh’s Dict (1944), pp 359-L & 368-R

Gases Liberated from Explosions Initiated by Impact. It has been known for a long time that in a true deton of HE, the major products are CO₂, CO, H₂O, N and H, while in thermal decomposition of expls, more complicated mixtures of NO₂, NO, N₂O, CO₂, CO, H₂, aldehydes etc. result. As it is of interest to know what kind of products are obtained when an expl is initiated by impact, Robertson and Yoffe (Ref 8) tested NG, PETN and RDX in a special vacuum impact machine. Their results showed that gases developed on impact approximate more closely those developed on thermal decomposition than those on deton. The results are in harmony with the hypothesis of a thermal origin of impact-initiated explns and with the slow initial burning velocities observed with the rotating drum camera. 

Gases Produced on Decomposition of Smokeless Propellants. Their volume was deter by P. Tavemier, MP 35, 259-72 (1953)
Gases Produced on Deflagration of Smokeless Propellants. Their Nonideal Behavior was discussed by P. Tavenier, MP 37, 269–304 (1955) & CA 51, 1610 (1957)

Gases Produced on Explosion or Detonation of Explosives. The usual gases are CO₂, CO, H₂O, N₂, O₂, NO₂, and H₂. For determining the compn of gases evolved on expln or detont, the test is conducted in a closed vessel, such as Bichel Bomb (described in Ref 1, pp 91–95 and in Vol 3 of Encycl, pp C331-R & C332-L), by the procedure described here under "Gas Volumes Produced on Explosion or Detonation of Explosives". After cooling the bomb, the gases are collected in a gasometer; their volume calc'd to 0° & 760mm Hg and then they are analyzed by one of the methods listed here under "Gas Analysis".

In ADL Report (Ref 3) are given compns of gases developed on detont of TeNMe (Tetranitromethane) alone and its mixture with a mt of RDX to obtain an Oxygen Balance to CO₂ equal to +10%. See Table G3

<table>
<thead>
<tr>
<th>Table G3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explosives</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>OB to CO₂</td>
</tr>
<tr>
<td>Gases, Volume Percent</td>
</tr>
<tr>
<td>CO₂</td>
</tr>
<tr>
<td>O₂</td>
</tr>
<tr>
<td>H₂</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>NO₂</td>
</tr>
<tr>
<td>Total Explosive accounted for</td>
</tr>
</tbody>
</table>

Composition of gases produced on detont of the following expls and given in Stettbacher (Ref 2, p 75) are reproduced here in Table G2

<table>
<thead>
<tr>
<th>TABLE G2</th>
</tr>
</thead>
<tbody>
<tr>
<td>For 1 kg of Explosive</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Gases:</td>
</tr>
<tr>
<td>CO₂</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>C (Soot)</td>
</tr>
<tr>
<td>H₂O</td>
</tr>
<tr>
<td>H₂</td>
</tr>
<tr>
<td>O₂</td>
</tr>
<tr>
<td>NO</td>
</tr>
<tr>
<td>N₂</td>
</tr>
<tr>
<td>NH₃</td>
</tr>
<tr>
<td>CH₆</td>
</tr>
<tr>
<td>C₆H₄</td>
</tr>
<tr>
<td>(CN)₃</td>
</tr>
<tr>
<td>CO₂/CO</td>
</tr>
<tr>
<td>Gas Volume, liters/kg</td>
</tr>
</tbody>
</table>
Experimental procedures for determination of gaseous products of explo of explosives by means of a device called the Crawford-Frazier-Jones Apparatus are described in Ref 1, but no comp of gases are given.


Gas-Generating Nondetonating Compositions are described in the following refs:

Refs: 1) J. Taylor, USP 2159234 & CA 33, 7116 (1939) (Gas-generating non-detonating comp suitable for use in blasting. It consists of a pressure-resistant, pressure-responsive container, a deflagrating ignition means and a deflagrating gas-generating compn capable of undergoing self-sustaining decomp without det.) 2) J. Taylor & A.C. Hutchison, USP 2604391 (1952) & CA 47, 1932 (1953) [High yield of gases and at a greater rate is produced on thermal decompos. of NGu or GuN (Guanidine Nitrate) if a small amt (2 to 20%) of Cu powder or Cu compd (such as CuCl or Cu2O) is incorporated. These substances act as sensitzers. The add of 1% V2O5 increases further the rate of burning]

3) Ibid, USP 2653086 (1953) & CA 48, 2376 (1954) [Two mixtures of gas generating, non-detonating compns are described: a) K chromate 20 & NGu (Nitrogrenaidine) 80% and b) NGu 80, Amm dichromate 10, DPHDEtUrea 5 & charcoal 5%, mixed in a ball mill and pressed in cylindrical form. The rate of burning of pressed chge was 0.07 inches/sec at a pressure of ca 100 atm.] 4) A.C. Hutchinson, USP 2710793 (1955) & CA 49, 13652 (1955) (Solid gas-generating units prep'd from 89-98.8% GuN or Nitrogrenaidine, 0.2-10% molybdc, ceric, or vanadic oxide and 0.25-1% asbestos fiber) 5) J.F. Williamson, BritP 724060 (1955) & CA 49, 14325 (1955) (Nondetonating, gas-generating expl charge for use in fiery mines prep'd from Mg(NO3)2, H2O, AN & wood flour; packed in a ported venting head container) 6) A.C. Hutchinson, USP 274816 (1956) & CA 50, 12444-46 (1956) (Solid gas-generating charges exemplified by GuN 88.75, 2,4-dinitroresorcinol 10, V2O5 0.5, asbestos fibers 0.5 and KNO3 0.25 (nitro or nitroso phenols and V2O5 are part of claim)] 7) M. Boyer, USP 2981616 (1961) & CA 55, 25260 (1961) (Gas-generating compns for pressurizing rocket-propellant tanks consisting of mixt of an azide and an oxidizing compd, eg, NaN3, 60 & NaNO3, 40%) 8) J.W. Rabern & N.J. Wilkaitis, GerP 1109577 (1958) & CA 56, 6232 (1962) (Gas generator based on AN and a binder) 9) A.T. Camp & F.G. Crescenzo, USP 3102834 (1963) & CA 59, 11182 (1963) (Gas generator based on NC 48, NG 31.2, triacetin 16.25, 2-nitrodiyphenylamine 1, Ethyl Centralite 1, PbO 1, CuO 1, cellulose acetate 0.5 and candelilla wax 0.05% has a burning rate of 0.225 inches/sec)

Gas Hydrates. They are gases (such as ethylene, propane and isobutane) which form clathrate (See Ref 2) compounds on contact with water. These compds are solid and insol in w. They usually form and exist at relatively low temps and high pressures. Anywhere from 6 to 18 moles of water may combine with each mole of gas, depending upon the nature of the gas.
Interest in the gas hydrates for many years was generated mainly because of the nuisance of such compounds forming in gas pipelines. In recent years, the compounds have been proposed as a means of precipitating water from salt solns (or sea water), thus yielding potable water.


Gas Ignition Point. Discussion of relationships between ignition point (autoignition) and drop ignition point (spontaneous ignition). Derivation of a formula for calcg drop point temps.


Gas, Illuminating. A gas used for production of light. It is prep'd by distillation of bituminous coal in small horizontal or vertical retorts. Other combustible gases may be used for this purpose, provided they contain sufficient amts of illuminants, such as benzene or ethylene. Some illuminating gases contain "natural gas" mixed with other gases (See also under Gas, Coal)

Ref: Riegel, "Industrial Chemistry" (1942), 270-71

Gasket Materials Used in Ordnance. Various types are described in


Gas, Lachrymatory. See Gas, Tear

Gas, Laughing. Same as Nitrous Oxide, N₂O, used as a dental and surgical anesthetic and to preserve perishable foods

Ref: Hackh's Dict (1944), 368-R & 580-R

Gasless Delay Detonators, Electric (German). These detonators used during WWII were prep'd as follows:

a) Detonator shells (Hülse) of Al having an outside diam of 7.20mm and lengths ranging from 52.5 to 85mm (depending on the delay required) were thoroughly cleaned and dried before loading. Cu shells also were used

b) Tetrayl was loaded in two increments (a total 0.7g) to serve as a base charge. This was followed by priming charge of 0.3g of 60/40 LA/LSt mixture and a perforated reinforcing cup, all pressed at 250kg/sq cm

Note 1: Tetrayl, LA and LSt were previously dried to a max moisture content of 0.1%

c) After keeping the loaded detonators for 3 days at 50°C in order to remove all traces of moisture, 50ml of loose intermediate compn was placed on top of the reinforcing cup

Note 2: The intermediate compn (powdered mixt of Sb and KMnO₄) formed a loose connection between the delay compn (to be loaded next) and the priming compn, LA/LSt. The intermediate compn burned with a strong flame which facilitated the ignition of the LA/LSt mixt. Misfires could take place if the delay mixt were placed in direct contact with LA/LSt

d) The next step was to press on top of the intermediate mixt the delay element congn a compressed powdered mixt of Sb & KMnO₄. The detonator shell was then crimped just above the upper end of the delay sleeve in order to provide a seal for the "Mipolam" sealing plug, described in Ref 4, p Ger 113-R

Note 3: Accdg to Ref 1, pp 5-6, the gasless delay powder (also called "gasless delay fuze powder") consisted of about 70% Sb pdr & 30% KMnO₄ pdr for slow burning, or about 46% Sb & 54% KMnO₄ for fast burning. The permanganate was ground in a disc or plate crusher mill to approx 80 mesh. The antimony
was ground from lumps in a vibratory ball mill and the powder was transferred by a screw feed into an air separator. The fines which did not exceed 10 microns in size were collected and blended with the permanganate by means of a tumbling mill. The resulting mix was compressed into tablets in a rotary multiple punch press. The tablets were then broken in a plate crusher mill and the resulting powder was used loose as an intermediate charge and compressed to form a delay element.

- The fuse head assembly (qv) consisting of bridge wire, igniter bead, two lead-in wires (insulated by Mipolam), and the Mipolam plug, was inserted in the detonator shell in such a manner that the plug rested on the shoulder of the detonator shell formed by crimping. A second crimping was then made above the plug and the lead-in wires were connected to a source of electricity when the detonator was to be fired.

Refs: 1) CIOS Report 24-3 (1945), pp 5-6 2) BIOS Final Rept 833 (1946), Item 2, Appendix A 3) "Manufacture of German Detonators and Detonating Compositions", PB Rept 95613 (1947), Sects B to L, incl 4) PATR 2510 (1958), pp Ger 63 & Ger 66

Gasless Delay Elements and Detonators Employing Them. See Vol 4 of Encycl, Section 4, Part F, pp D863-R to D868-R

Gasless Delay Fuze Primers. See Vol 4, pp D868-R to D869-L

Gasless Delay Powders for Ammunition Fuze Applicators are described in the following Picatinny Arsenal Technical Reports:

Reps: 1) D. Hart, "Gasless Powders for Delay Elements of Fuzes", PATR 1239 (Feb 1943)
2) D. Hart, "Gasless Powders for Delay Elements of Fuzes", PATR 1281 (April 1943)
3) D. Hart, "Gasless Powders for Delay Elements of Fuzes", PATR 1406 (March 1944)
4) S. Sage, "Manufacture of Barium Chromate Delay Powder on a Semi-Plant Scale", PATR 1432 (July 1944)
5) D. Hart, "Gasless Powders for Delay Elements of Fuzes", PATR 1513 (March 1945)
6) J.E. Osmun, "Surveillance Tests on M16A1 Primer Detonators Containing Type I, Class B Delay Powder", PATR 1546 (July 1945)
7) M.C. Epton, "Long Range Development of Delay Powders for Ammunition Fuze Application (Bomb Fuzes)", PATR 1686 (April 1948)
8) D. Hart, "Long Range Development of Delay Powders for Ammunition Fuze Application", PATR 1733 (June 1949)
13) B. Werbel, "Development of Delay Powders", PATR 2249 (Sept 1955)
14) B. Werbel & S. Lopatia, "Development of Delay Powders", PATR 2477 (April 1958)

Gasless Explosives Investigated in Russia. The following mixes, which produced no gaseous materials in either the initial or final stage, were investigated by Belyaev (Ref):

Mixure No 1. 3.6KClO₃ + FeSi₆₆ s =
3.6KCl + 0.5Fe₂O₃ + 4.65SiO₂

Mixure No 2. KClO₃ + 2Al = KCl + Al₂O₃

By using No 8 detonator and Lead Block Compression Method, which was a modification of Hess' Method, described in Vol 3 of Encycl, p C492 as the "Brisance Meter of Hess", Belyaev obtb the compression values in mm shown in Table G4
### Table G4

<table>
<thead>
<tr>
<th></th>
<th>Mixture No 1</th>
<th>Mixture No 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diam of chge, mm</td>
<td>40 58 77.5</td>
<td>40 58 77.5</td>
</tr>
<tr>
<td>Wt of chge, g</td>
<td>50 240 480</td>
<td>50 240 480</td>
</tr>
<tr>
<td>Compression, mm</td>
<td>0 0.7 15.1  5.4 16.73 21.55</td>
<td></td>
</tr>
</tbody>
</table>

Deton velocities as ded by method of Dautriche, described in Vol 3 of Encycl, p C311-R, were:

- **Mixture No 1**: 1170m/sec in a tube 20mm diam and 1270 in a tube 27mm diam. No densities were indicated
- **Mixture No 2**: 1370m/sec in a tube 21mm diam and 1370 in a tube 40mm diam. No densities were indicated

*Note*: Both mixts contained KCl in their products of expln. As the temp of expln was higher than the critical for KCl, it means that KCl should have been in the vapor state during the expln process and consequently behaved like a gas. As the volume of KCl vapor was small, in comparison with those given off by ordinary expls, it may be considered negligible and the mixts gasless

*Ref*: A.F. Belyaev, ComptesRendusAcadSci (Russia) 46, 107–09 (1946) & CA 40, 4531 (1946)

### Gasless Ignition Powders

1) **A-1A Composition**:
   - Zr 65.0±1.0, iron oxide 25.0 1.0 & diatomaceous earth 10.0±1.0%
2) **F-33B Composition**:
   - Zr 41.0±1.0, iron oxide 49.0 1.0 & diatomaceous earth 10.0±1.0%

*Ref*: Specification MIL-P-22264 Wep, Amend 2, 1962

### Gasless Mixture 668/Mn

- Mn 10, Cu 30, Si 30 & PbO₂ 30%. Pressure on heating of this mixture was developed by sublimation of metals

*Ref*: W.A. Show, "Development of an Incendiary Peller", Tech Command Army Chem Center, Md Rept TCR-59 (May 1950)

### Gasless Powders for Delay Elements of Fuzes

Many compns were developed by Dr Hart in the Pyrotechnic Laboratory of Picatinny Arsenal. They are described in the following Picatinny Arsenal Reports:

- **1239** (Feb 1943). Compositions contg Ba chromate, manganese and sulfur show promise for use in M54 Time Fuze and in the M16 Delay Element
- **1281** (April 1943). New igniter compn for ammunition contains Pb chromate 50.0, manganese 32.5 & sulfur 17.5%
- **1406** (March 1944). New fuze powd contains Ba chromate 74–77, manganese 20–22 & sulfur 3–4% and is suitable for use in 8–11 second M16A1 Delay Element of bomb fuzes
- **1513** (March 1945). Improved 8–11 second delay powder contains Ba chromate 70.9, manganese 27.1 & sulfur 2.0% with 2–3 parts ethyl cellulose added

**Gasless Reactions**. Gasless compns consist of finely powdered reducing agents and oxidizing agents mixed together and often consolidated by compression. The chem processes are exothermic oxidation-reduction reactions, commonly involving transfer of oxygen from a metallic oxide or oxy-salt to a metal

Investigations have been carried out on compressed mixts of finely divided iron & Ba peroxide, and iron & K dichromate, which undergo incandescent reaction when ignited. Also systems using finely divided iron, manganese & molybdenum as reducing agents and Ba peroxide, K permanganate and the nitrates of K, Pb, Sr & Ba as oxidizing agents were studied. Three other systems — iron/K dichromate, sulfur/Ba peroxide and Si/K dichromate were investigated in a range of proportions and the heat evolved in the reactions was measured

One of the best-known gasless reactions is Thermite which is comprised of a mixt of Al powder & iron oxide:

\[ 3\text{Fe}_2\text{O}_3 + 8\text{Al} \rightarrow 4\text{Al}_2\text{O}_3 + 9\text{Fe} \]

The quantity of heat released is 850cal/g and the temp reached is enough to melt the iron. This reaction and its applications were discovered & developed by Hans Goldschmidt (1861–1923). The Thermite type reaction was used in making incendiary bombs during WWII. Thermite is more effective when used with
add Al powder, Ba nitrate & sulfur as an igniting means for Mg bombs

One of the most useful & important applications of gaslesscompacts is in delay elements of electric detonators. There is a vast amount of info in the patent literature describing these compacts. One commonly used mix is antimony & K permanganate:

\[2 \text{Sb} + 10/3 \text{KMnO}_4 \rightarrow 10/3 \text{MnO}_2 + \text{Sb}_2\text{O}_3 + 5/3 \text{K}_2\text{O}\]

which liberates 390cal/g. A Canadian Industries Limited patent describes a short period delay detonator comprising a homogeneous mix of 70/30 Misch metal/Al 13.4, silicon 24.1 & red lead 62.5% yielding gasless reduction products. One ICI patent claims a compn of red lead & powdered Ti or Zr can be used for delays of 10–1700 milliseconds, and is insensitive to ignition by friction.

In order to initiate the delay element it is necessary to use an electric fusehead which is also gasless. One such fusehead is made by dipping the bridge wire in a suspension of a mix of Zr powder 50 & Pb 2-Mononitroresorcinol 50% in a 5% soln of NC in amyl acetate.

Other interesting applications of gasless compacts are those used in the hot tube safety igniter for initiating blasting devices of the "Hydrox" type. The heat of reaction of a chge of Zn powder 60 & K permanganate 60% is sufficient to ignite Hydrox powder, but not high enough to ignite methane/air mixts or coal dust/air mixts which occur in fiery coal mines. Also developed during WWII was a self-heating food can capable of heating its foodsuffs content to a desirable temp in a few mins and yet not much bulkier than an ordinary can contg the same amt of foodstuff. The heating mixt most suitable is a 50/30 mixt of finely powdered Ca silicide & FeO4. Easy ignition of this mixt is ensured if a priming layer of Ca silicide/red lead 30/70 with the addn of 10% china clay to slow the rate of reaction.


Gas-Liquid Chromatography. See under Gas Chromatography

Gas Liquor. Same as Ammoniacal Liquor, briefly described in Vol 1 of Encycl, p A305-L

Gas, Mond. See under Gas Producer

Gas Munition. Munition such as bomb, projectile, pot, candle or spray tank contg a chemical agent (See Vol 2 of Encycl, pp C165-R to C178-R) and means of release

Ref: Glossary of Ordn (1959), 133-R

Gas, Natural. Any gas issuing from beneath the earth's crust thru openings or bored wells, may be called natural gas. The most important natural gas is that consisting of a mixture of hydrocarbons. Such gas is often found in and near coal or petroleum deposits in many countries, including the USA. Many gas wells do not yield oil, but an oil well always produces gas and oil. Such a gas is known as "casinghead gas" (Ref 1a, p 275)

Typical composition of an American natural gas is: methane (with some ethane, propane etc) 92, hydrogen 3, illuminants 3 & nitrogen 2. Heating value is 1000 BTU per cu ft. Volumes of air necessary to bum one vol of gas are 9.73. Riegel (Ref 1a, p 271) gives the following compn: methane 90.0, ethane 8.8 & N2 1.2. Total combustibles 98.8 and BTU 1100 per cu ft

Some natural gas, eg, that issuing near Sicilian volcanos, contains sulfur ingredients as a chief ingredient. This gas may be used for the preparation of sulfur

Natural gas has been known for many centuries. For instance, near Baku, Caucasus, a temple of a religious sect who "worshipped the fire", existed long before the Russians arrived there. The fire was produced by the burning of natural gas. The first commercial use of the gas in the USA was in 1820 at Fredonia, NY, when a few buildings were
supplied from a nearby shallow gas well. From that time until about the last part of the 19th century, only a small quantity of gas was used. After that the consumption of natural gas began to grow, reaching about 500 billion cu ft in 1910. In 1964 about 15 trillion cu ft were produced and the industry is still growing. At present, about 30 states have known deposits of natural gas. 


Gas, Noxious. Any poisonous (toxic) gas or a gas with strong unpleasant odor. Ref: Hack's Dict (1944), 368-R

Gas Oil. A liquid petroleum distillate with a viscosity and boiling range (450-800°F), between kerosene and lubricating oil (Ref 2, p 528-L). Under the title Oil Gas of the same ref, but p 825-R, is defined a gas made by the interaction of oil vapors and steam at high temps by the method used for prep of water gas. A typical analysis of oil gas is CO 10.4, hydrogen 47.6, methane 27.0, CO₂ 4.6, illuminants 4.2, oxygen 0.4 & nitrogen 5.8%. BTU/ cu ft 554

Acdng to Riegel (Ref 1), compressed oil gas is known as Pintsch Gas. Refs: 1) Riegel, "Industrial Chemistry" (1942), 277 2) CondChemDict (1961), p 528-L (Gas Oil), p 825-R (Oil Gas); 8th ed (1971), 411-R (Gas Oil) & 642-L (Oil Gas)

GASOLINE (Gasolene or Petroleum Benzine) (Petrol by the British; Petroleumensenz or Petroleumbenzin in German; Benze in petrole, Petrole or Essence in French; Benzina or Gasolina in Spanish; Benzina in Italian; Neftianoy benzin in Russian)

Gasoline is a colorless, transparent, highly volatile and combustible liquid with a density of about 0.75; used as a fuel in internal combustion engines, as a fuel in liquid rocket propellants, in Napalm Flame Throwers and for making rubber. Originally, gasoline was obtained by fractionating crude oil and comprised the distillate boiling between about 60° and 200°. This is now called "straight run gasoline". The composition of this varies with the type of petroleum used, and may be divided into paraffinic, naphthenic and aromatic.

There is also the so-called "casinghead gasoline", which is "natural gasoline" obtd by the recovery of the normally liquid hydrocarbons which are contained in the natural gas present in oil wells, and from some oil wells which give natural gas not associated with petroleum. Present-day American gasoline is a blend of natural gasoline, straight run gasoline and the products of various processes, such as cracking and alkylation. The Germans obtd nearly all of their gasoline during WWII from coal. Some European countries use gasoline cong as much as 40% alcohol as motor fuel.

Cracking gas was briefly described in Vol 3 of Encycl, p C552-L, while cracking processes, such as of Dubbs and of Houdry are described in Ref 4, pp 429-31. See also Ref 9, p 528-R

Alkylation process for the production of high-octave gasoline is described in Ref 4, p 442 & Ref 9, p 41-L
Other methods for prep of high-octane number gasolines are described in Ref 4, pp 441–42.

Method of prep of gasoline by vapor-phase hydrogenation of lubricating oil is described in Ref 4, p 437.


Gasoline, High Octane Number. It has been required that present aviation gasoline must be antiknock, which means that its octane number must be as high as 100. The octane number is the rating of gasoline as to its antiknocking properties on the basis of a standard sample consisting of iso-octane (2,2,4-trimethylpentane) and n-heptane mixed in various proportions. Heptane tends to knock, while iso-octane has marked antiknock properties. By mixing the two in all proportions, a series of fuels is obtained which covers the whole scale of possible mixtures. For example, a gasoline has an octane number 75 if, on compressing it in a standard engine, it begins to knock with the same compression ratio which causes a mixture of 75 parts iso-octane and 25 parts of n-heptane to develop a knock in the same engine under the same conditions (Refs 1 & 2).

According to Riegel (Ref 1, p 441), the 100-octane fuel for aircraft can be prepared by mixing: iso-octane 40, aviation gasoline (74-octane number) 45 & iso-pentane 15% with 3% tetraethyl lead. The iso-pentane supplies the volatility at low temps which the iso-octane lacks.

The term "aviation gasoline" indicates the gasoline which becomes the base of the aircraft fuel. It is either "straight-run" or "cracked gasoline", prep'd by the Houdry process. Its boiling range, 100°F (37.78°C) to 249°F (120.56°C), is lower than that for std gasoline.


Gasoline, Polymer. A gasoline produced by polymerization of low molecular wt hydrocarbons, such as ethylene, propane, and butenes. It is used in small amounts for blending with other gasolines to improve their octane number.


Gasoline, Reformed. A high-octane gasoline obtd from low-octane gasoline by heating the vapors to a high temperature or by passing the vapors thru a suitable catalyst.


Gasoline, Straight. Gasoline produced from petroleum by distillation, without using cracking or other chemical conversion processes. (See also under GASOLINE)


Gas, Petroleum. See Gas, Oil

Gas, Pintsch. Compressed Oil Gas

Gas (or Vapor) Pockets (Bubbles) in Liquid and Solid Explosives.

The presence of minute gas or vapor...
pockets (bubbles) in expls renders them more sensitive to impact, friction and initiation. This is due to adiabatic compression, which takes place in these bubbles on impact, etc., resulting in the evolution of a large amount of heat and increasing the temp in the neighborhood of the bubbles. This heat causes the deto of the expl surrounding the bubbles, which means that these bubbles are the spots where initiation takes its origin. This theory originated by F.P. Bowden et al is described in Vol 2 of Encycl, p B127 under “Birth (Initiation) and Growth of Explosion in solid and Liquid Explosives Initiated by Impact, Friction, etc (10 refs)

As an example of the practical application of the knowledge may be cited the sensitivity of freshly prep’d Gelatin-Dynamites, as compared with those lying in storage. The tests were conducted before WWII at Apache Powder Co, Benson, Arizona and communicated to us by Dr I.A. Grageroff. A brief description was given under “Aging(Aging) of Dynamites”, in Vol 1 of Encycl, pp A110-R to A112-L. In addn, Dr Grageroff stated that some Gelatin-Dynamites decreased in “sensitivity to sympathetic initiation”, as deter by the “gap test”, from 6 inches to 1–2 inches after storage for several months. If, however, cartridges of these “aged” Gelatins were lightly rolled on a table by means of a smooth board, in such a manner as to inclose some bubbles in the cartridge, the gap sensitivity was restored to nearly normal. In order to show more definitely that the decrease in sensitivity was due to the disappearance of air bubbles, the freshly prep’d Gelatins were subjected to prolonged vacuum in order to remove air bubbles. The result was the same as for cartridges stored for a long time; the gap value dropped to 1–2 inches.

The theory of Bowden et al was disputed by W.A. Hargreaves (See p A111-L of Vol 1), who proposed his own theory. This theory was favored by Dr J. Mayer, who worked at Explosives Plant, Villa Maria, Argentina. If Hargreaves theory were accepted, it would be difficult to explain the “rejuvenation” of aged Gelatin Dynamites, as was done at Apache Powder Co Plant. It seems that combination of both theories could be accepted.

Gas, Poisonous. Same as Gas, Toxic described in Vol 2 of Encycl under CHEMICAL AGENTS, pp C165-R to C171

Gas Pressure Cartridges (Gasdruck patronen in Ger, Cartouches à pression à gaz in Fr; Patrones de presión a gas in Span). Gas pressure cartridges are used to power cartridge actuated devices (CAD’s). A CAD is a pressure actuated mechanism using propellant generated gases to produce mechanical action other than expelling a projectile. See Vol 2, p C70-R for further description.

Ref 1 describes German developments up to 1940 of gas pressure cartridges for airplane engine starters or for pilot ejection seats. An airplane starter, “Druck patronen DP 50/144”, was made with the base of the case of aluminum of Kail 4 with Fuse VI and also using a special slow burning cellulose for the rest of the case. The charge was a coarse grained perforated powder of 1000 cal heat content. An ejection seat cartridge, HG 34/4, contained 34g of a special powder made of a mixture of Nitrocellulose, DEGDN & Nitroguanidine. The igniter was 4g of strongly pressed Black Powder.


Gas Pressures Developed on Deflagration of Propellants. See Vol 1 of Encycl, p XX


Gas Pressures Developed on Explosion or Detonation of Explosives

In Vol 2 of Encycl, pp B180–B184, blast effects produced in air, earth and water were described. It was stated on p B180-R that,
when a HE bomb detonates, the solid bursting charge is rapidly converted into gaseous products. This process, occurring in approx 0.0001 sec, develops very high pressures and temperatures. These values vary with the chem compn of the expl but their order of magnitude is 100000 atm (700 tons/sq inch) pressure and about 3000°C (5400°F) temperature. Of the total energy available from the expl, as much as half may be used to expand and break the casing (bomb body), while the remainder to compress the surrounding environment. This latter energy is responsible for blast effects. Bombs intended to be used for blast effects, were constructed during WWII of thin casing.

Prior to WWII, expls used in bombs were tested by Trauzl Lead Block Method and the assembled bombs were detonated in an enclosure to determine the number and penetrating power of the bomb fragments (See Panel Fragmentation Test in Vol 3 of Encycl, p 349 and Fragment Velocity Test on p C350). As these tests did not give any quantitative values for blast effects, special tests were developed, first in England (1938) and later in the USA. A brief description of these tests and refs is given under Blast Meters in Vol 2, pp B214-R & B215-L.

In expressing the blast effect of an expl, it is necessary to describe its peak pressure and impulse (See Vol 2, p B180 and Fig giving Typical Pressure-Time Record for the Blast From a Bomb).

In Vol 4 of Encycl, p D483, it was stated that one must distinguish between pressure produced on detonation by gases and total pressure developed on detonation. It was also said that pressure can be produced by expls evolving no gases, such as by reaction:

\[ 2\text{Al} + \text{KClO}_3 = \text{Al}_2\text{O}_3 + \text{KCl} \]

but accdg to C. Dunkle the products of reaction formed at high temp of expln are gaseous KCl, AlO, AlO and oxygen. The AlO does not form until the products cool. Dunkle also stated that “total detonation pressure” is also known as stagnation pressure, and is equal to the sum of static pressure and dynamic pressure.

Accdg to Cook (quoted in Vol 4 of Encycl, p D484-L), the detonation pressure \( p_d \) cannot be measured directly (at least in condensed expls), owing to its transient nature and its exceedingly high magnitude. This pressure can, however, be accurately determined by the hydrodynamic equation listed in Vol 4 of Encycl, p D484-L.

A more accurate, but rather complicated formula is given on p D484-R and a rather simple formula by Dunkle (p D484-R).

Other formulas for calcn of pressure are given in Vol 3 of Encycl, p C330, Sterntacker (Ref 2, p 71), Gorst (Ref 4, p 56), Bandurin & Rukin (Ref 6, p 70) and Gorst (Ref 7).

The following calc'd values of “total detonation pressures” are given in Table G5, from Vol 4 of Encycl:

<table>
<thead>
<tr>
<th>p D487</th>
<th>RDX</th>
<th>346000 at d 1.785</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>TNT</td>
<td>200000 &quot; 1.64</td>
</tr>
<tr>
<td>p D492</td>
<td>PETN</td>
<td>95300 &quot; 1.00</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>140300 &quot; 1.20</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>195500 &quot; 1.40</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>262800 &quot; 1.60</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>91800 &quot; 1.00</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>160400 &quot; 1.28</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>218100 &quot; 1.45</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>259100 &quot; 1.61</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>83000 &quot; 1.03</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>120700 &quot; 1.23</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>164600 &quot; 1.39</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>239400 &quot; 1.63</td>
</tr>
<tr>
<td>&quot;</td>
<td>TNT</td>
<td>68700 &quot; 1.00</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>132800 &quot; 1.29</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>178000 &quot; 1.46</td>
</tr>
<tr>
<td>&quot;</td>
<td>&quot;</td>
<td>216200 &quot; 1.59</td>
</tr>
</tbody>
</table>

The values for calculated total pressure, given in the book of Gorst (Ref 4, p 75), are reproduced in Table G6.
Table G6

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Density</th>
<th>Total Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT (Trotl, in Russ)</td>
<td>1.59</td>
<td>193000</td>
</tr>
<tr>
<td>TNT</td>
<td>1.45</td>
<td>157000</td>
</tr>
<tr>
<td>RDX (Gheksoghen, in Russ) phlegmatized</td>
<td>1.62</td>
<td>296000</td>
</tr>
<tr>
<td>Tetryl (Tetril, in Russ)</td>
<td>1.61</td>
<td>229000</td>
</tr>
<tr>
<td>PETN (Ten, in Russ)</td>
<td>1.60</td>
<td>255000</td>
</tr>
</tbody>
</table>

Davis (Ref 3, p 132) gives the values (See Table G7 for gas pressures detd by exploding the materials, at densities indicated, in a small bomb and measuring the pressure by means of a piston and obturator)

Table G7

<table>
<thead>
<tr>
<th>Explosives</th>
<th>Densities of Loading</th>
<th>Pressures in kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>Trinitrobenzene (TNB)</td>
<td>2205</td>
<td>3050</td>
</tr>
<tr>
<td>Trinitroaniline (TNA) or Picramide</td>
<td>2080</td>
<td>2885</td>
</tr>
<tr>
<td>Trinitrophenol (TNPh) or Picric Acid (PA)</td>
<td>2150</td>
<td>3055</td>
</tr>
<tr>
<td>Trinitroresorcinol (TNR) or Stypnic Acid</td>
<td>2080</td>
<td>2840</td>
</tr>
<tr>
<td>Trinitrotoluene (TNT)</td>
<td>1840</td>
<td>2625</td>
</tr>
<tr>
<td>Trinitro-α-cresol (TNCr)</td>
<td>1760</td>
<td>2480</td>
</tr>
<tr>
<td>Trinitro-α-xylene (TNX)</td>
<td>1635</td>
<td>2340</td>
</tr>
<tr>
<td>Trinitromesitylene (TNMes)</td>
<td>1470</td>
<td>2200</td>
</tr>
<tr>
<td>Trinitronaphthalene (TNN)</td>
<td>–</td>
<td>2045</td>
</tr>
</tbody>
</table>

This Table shows that TNB is the most powerful explosive among the nitrated aromatic hydrocarbons. One amino group, as in TNA, reduces its strength and so does one hydroxyl group as in TNPh (PA). Two hydroxyl groups have less effect than one methyl group as in TNT and TNR is a stronger expl than TNT. One methyl group reduces the strength of TNB less than do two methyls in TNX, and the weakest is TNMes with three methyls. TNT is a stronger expl than TNCr, which differs from it in having an hydroxyl group. The weakest of the above expls is TNN because it contains more C's than any of them.

The Table on p 157 of Davis (Ref 3) gives the following values for nitratated derivatives of naphthalene at density 0.3: MNN 1208, DNN 2355, TNN 3275 and TcNN 3745. The value given here for TNN is higher than those given on p 132 of Ref 3.

The values given in Ref 3 on p 169 for TNR and TNPh, 2260 & 2350, respectively, at density 0.2 are higher than those given on p 132.

The following values are given in Table of Ref 3, p 172: TNPh 2310, 2350 & 2210 at d 0.2 and 3230 at d 0.25; Trinitroanisol – 2222, 2250 & 2145 at d 0.2 and 2850 at d 0.25; Trinitrophenetol – 1774 at d 0.2, 2490 at d 0.25 and 3318 at d 0.30

In Table on p 175 (Ref 3) are given pressures for TNA 2356 at d 0.20 & 3110 at d 0.25; for Tetryl at d 0.20 – 2423 and at d 0.25 – 3243.

In Table on p 182 (Ref 3) are given the following pressures at d 0.3 and temps indicated: Tetryl 4684 at 291°C, TNPh 3638 at 2419°C, TNN 3749 at 2060°C and TNN 3925 at 2356°C

Devices for experimental determinations of pressure of gases developed on expln or detonation are described in Vol 3 of Encycl, pp C330-R to C345-R, under "Closed Bomb (or Vessel) and Instruments for Measuring Pressures Developed by Explosives or Propellants".

Vertical bomb of Dolgov used in Russia instead of horizontal Bichel Bomb is described by Varemenko & Svetlov (Ref 5, p 75 and Fig 34). This bomb was also used for determination of volume of gases developed on expln.

Manometric bomb used in Russia for dem pressure of gases developed on deflagration of propellants is described by Gorst (Ref 4, pp 56–8 and in Figs 10, 11, 12, 13 & 14) and his new edition (Ref 7)
A detailed description of Bichel Closed Bomb employed in 1931 at USBurMines was given on pp 85–87 of Ref 1 (under the name Bichel Gage), together with description of procedure used at that time. The Fig shown on p 86 of Ref 1 is just a photo of exterior view. A clearer idea of construction can be obtained from Fig of Vol 3 of Encycl, p C331-R and from Fig on p C332-L.

Procedure described in Ref 1, pp 84–95 was used to determine the maximum pressure a mining explosive would exert if exploded in a space that fills completely, and all of the heat set free by the chemical reactions that take place being retained by the products of explosion. Briefly it means: "maximum pressure of the explosive in its own volume".

Equipment. At the time of publication of Ref 1 (1931), there were two Bichel Closed Bombs at USBurMines, each of them made of strong cast steel. The No 1 apparatus had an interior capacity of 15 liters, while the No 2 was of 20 liters. Their walls were 12.5 cm thick. The heads of their cylinders were provided with lead gaskets, which were secured in place by 12 heavy stud bolts and an iron yoke. For exhausting the air, there was a tube inserted in a hole bored in an upper segment of each cylinder (See Fig on p C332-L of Vol 3 of Encycl), near one end. Exhaust tube of each cylinder was connected with a rotary, vacuum-air pump, driven by a 2-HP motor and provided with a valve which excluded the outside air after the desired vacuum was reached (usually 50±5 mm of Hg). In the upper segment of the cylinder, on the end opposite the exhaust tube, was an opening for the insulated plug that provided a means of conducting the electric current to the electric detonator and prevented air entering the cylinder while it was being exhausted. It also prevented escaping of gases after the expl was fired and while considerable pressure existed in the cylinder. A 3rd perforation, made in the top of each cylinder, allowed a properly ganged tube to be inserted in this aperture. The tube was provided with a piston 0.3937 cm diam, which could be moved up and down within the tube and was resisted by one of the four springs provided for this purpose. These springs exerted different pressures. They were marked 15 mm 4 kg, divide by 0.60 mm = 1 kg/sq cm; 10 mm, 6 kg divide by 0.40 mm = 1 kg/sq cm; 8 mm, 8 kg divide by 0.32 mm = 1 kg/sq cm and 10 kg divide by 0.24 mm = 1 kg/sq cm. It was desirable to select a spring that gave a curve 35±10 mm high on the paper or card attached to the drum described below. A stylus was mounted on one end of lever, the other end of which was fastened to the upper end of the stem of the piston in such a manner that while free to move vertically, the stylus should remain in the same vertical plane as long as the gases generated in the cylinder exerted pressure upon the piston.

Attached to the upper part of each apparatus and to the rear of the piston rod bearing the stylus, was a support carrying a recording drum with indicator paper ribbon attached. The drum was mounted to rotate horizontally about a vertical axis. The mechanism by which the drum was rotating was geared to an electric motor that ran at a constant speed, that could be accurately measured by means of a speed counter. Hence, the curve drawn on paper ribbon could be resolved with accuracy into its components of horizontal translation of the paper and vertical elevation of the stylus at the different periods throughout the expl.

Usually the drum rotated at a speed of 412 rpm. In the center of each apparatus was a small wire support upon which the cartridge of expl was laid, thus preventing the destructive effects on the walls of the cylinder that an expl exerts when it is detonated in contact with a surface.

Apparatus No 2, being constructed in the same manner and fitted with similar appliances as No 1, was further provided with four solid steel cylinders which served to reduce the volume of the chamber while varying its cooling surface. Diameters of cylinders were 17.78 cm, while heights were 20 cm for one and 6.67 cm for each of the remaining three. While Bichel apparatus No 1 had a cooling surface
A = 3914 sq cm, apparatus No 2, with large solid cylinder inside had a surface B = 6555 sq cm and a surface C = 7624 sq cm when the large solid cylinder was replaced by three small ones.

Procedure for Determining Pressure of Explosive in its Own Volume. The chge required to test a permissible expl at BurMines was 200±5g (of expl itself), to which was added the proportional amt of the wrapper. After removing the head of the Bichel cylinder and wiping it dry inside, the chge of expl, provided with a No 6 electric detonator was placed on the wire support. One leg of detonator wire was fastened to the wire that passed thru the insulated plug on the upper segment of the cylinder, while the other leg was grounded to the gage thru the iron support with which it was in contact. The head was then placed on the open end of the cylinder and secured to it by nuts screwed on to stud bolts, which were fastened to that end of the cylinder. The cylinder was then exhausted until the vacuum reached ±0±5mm, the difference betw the barometer and manometer readings. After bringing the temp of the gage to 22±5°, the charge was fired by electric current and then the cylinder allowed to cool while the indicator continued to function.

As was mentioned above, the gage spring was selected to produce a curve 15±10mm at maximum pressure, but if the 1st trial failed to produce such a curve, another spring was tried, etc until a satisfactory one was found. The spring chosen as satisfactory was then used in all of the trials of the same expl under test. A careful record was made of the spring used, and its effect was noted in each experiment made.

After completion of each test, using cooling systems A, B and C, the heights of curves on recording paper were measured and the pressure, P, developed in the gage was computed to the nearest 0.01 kg/sq cm by dividing the height of the curve in mm by the value for the particular spring used (one of the four listed above). Each value was expressed to the nearest 0.01 mm as being equi-

valent to 1 kg/sq cm.

If value A is the pressure developed with cooling system A, value B with the cooling system B and value C with the cooling system C, then pressure shown on the curve is:

\[ P = 1911A + 0.5B - 1.411C \]

This pressure P, divided by the charge density (defined as the volume of the chge divided by the volume of the bomb), gives the maximum pressure of the expl in its own volume after elimination of cooling-surface influence.

To simplify the computing of the pressure (M) in its own volume, the formula:

\[ M = \frac{VPS}{W} \]

was adopted. Here V = volume of the Bichel cylinder (15000cc); P = pressure obtd from the curve; S = apparent specific gravity of the cartridge as dtd in the physical examination; and W = weight of the chge in grams. M was expressed to the nearest kg/cm. For expressing in psi, it is necessary to multiply kg/sq cm by 14.2232.

Determination of Pressure of Low Explosives. In testing low expls, such as Black Blasting Powder, the charge was usually 300g, plus 2.5g of newspaper wrapping per 100g of BkPdr. The chge was fired by means of an electric igniter. Firing could be done either in vacuum or with air under atmospheric pressure. The measurement of pressure from the indicator cards was as follows: The maximum pressure was usually reached in about one revolution of the drum and continued for approx another revoln. The number of revolns and fractions thereof was measured from the firing to the point where the pressure began to fall owing to the cooling of the gases. At this point the maximum pressure was scaled off, and the average fall in pressure thru three succeeding revolns was added. This sum gave the corrected normal pressure.

See also "Gases Produced on Explosion or Detonation of Explosives" and also "Gas Volumes Developed on Explosion or Detonation of Explosives".

Determination of pressure using Crawshaw-
made at low temp so that the amount of ammonia in the coal may be conserved and later recovered

A typical compn of producer gas is given on p 271 of Ref: CO, 5.2, ethylene 1.0, oxygen 0.2, CO 26.3, hydrogen 14.4, methane 1.8 & nitrogen 51.1. Total combustibles 43.5 and BTU per cu ft 155.6

2) CondChemDict (1971), 731-L

Gas Pyrofax. It is propane, \( \text{C}_4\text{H}_8 \) (bp \(-42.5\,^\circ\text{C}\)), compressed in steel cylinders which are transportable

Ref: Riegel, "Industrial Chemistry", (1942), 277

Gas, Producer and Mond Gas. A gas obtb by burning coal or coke with a restricted supply of air. It is made in steel, brick-lined vessels such as 10ft in diam and 12ft in height (See p 274 of Ref with Fig 100). Any low-grade fuel may be partly burned, while steam in addn to air is sent into fire continuously, while fuel is dropped into apparatus at constant rate. The resulting producer gas passes out continuously, while the ashes are removed continuously by a sweeper in the water seal at the base. Numerous types of producers are on the market.

The reactions are the same as those which take place in a water-gas plant (qv); but in producer gas there is contained all the nitrogen entering with air for combination; hence, total combustible constituents of producer gas and the heat value per volume are lower than those of water gas.

The air-steam mixture (approx 7 vols of air for 1 vol of steam) is forced into app by means of an injector. The amt of steam used for 1 lb of coal gasified lies betw 0.3 and 0.5 lb. The vol of gas produced from bituminous coal is about 60 cu ft; semibituminous yields 30 and lignite 28 cu ft.

The so-called Mond Gas is producer gas

Gas Shells. No casualty-producing gas shells were used until near the end of WWI (June 1915) when the Germans brought out their K shell. The allies began firing such shells in Jan 1916. From then on the percentage of gas shells used on both sides steadily increased. By far the greatest number of all gas shells used in WWI was fired on the Western Front, next came the Eastern Front, and the Austro-Italian Fronts followed.

Unlike HE shell which had been fully developed and were std munitions 30 yrs before WWI, gas shells had to be hastily improvised & developed under stress of war conditions. Many of the early gases used in artillery shell proved unsuitable or were not adapted to field conditions. Thus, out of more than 50 chem substances loaded into artillery shell, only 4 or 5 proved effective in battle. Often the efficiency of a shell could be definitely ascertained only after a large number of rounds had been fired. For example, the French Vincennite shell was filled with a mixt of hydrocyanic acid & arsenic trichloride, which had a marked toxicity in lab tests. Yet, after 4 million shells were filled with this mixt it was not an effective gas under battle conditions.
In addition to inefficient toxic gases, there were a large number of shells of the laceratory & irritant types not intended to produce casualties, but to harass the enemy. When the various noncasualty-producing shells are subtracted from the total, a very high casualty power for successful types, such as phosgene & mustard shells, is disclosed. Considering the seven countries engaged in chemical warfare during WWI (Austria, England, France, Germany, Italy, Russia & USA) one casualty was produced for each 100 rounds of non-gas artillery ammo, but one casualty for each 45 rounds of toxic-gas shells resulted.

Much has been written concerning the horrors of gas warfare and the cruel & inhuman consequences resulting. Some of these alleged horrors were pure propaganda deliberately disseminated to influence world opinion. In general, gas caused less suffering than wounds from other weapons. Chlorine, the first gas used, did cause strangulation & high mortality, but when troops were supplied with gas masks, chlorine became the most innocuous of toxic gases and was the least feared by both sides.

Two other principal lethal gases, phosgene & chloropicrin, in high concentrations caused instant collapse, but no suffering. One of the most striking evidences of the effectiveness of gas shells & chemical warfare agents was their rapidly increasing use as WWI progressed.

There is no doubt, had the war continued, the campaign of 1919 would have been largely a chemical war. This phenomenal rise in the use of chemicals from unknown obscurity in 1915 to the position of a military agent of the first magnitude in 1918 was without parallel in the history of warfare up to that time.


The Presence of Explosive or Combustible Gas in Air is described in
Refs: 1) Mine Safety Appliances Co, Brit P 520993 & CA 36, 1168 (1942) and
2) R.E. Hartline, USP 2279397 & CA 36, 5352 (1942)

Gas, Toxic. Same as Gas, Poisonous described in Vol 2 of Encycl, under CHEMICAL AGENTS, pp C165-R to C171

Gas Turbine. A heat engine that converts some of the energy of fuel into work by using gas as the working medium and that commonly delivers its mechanical output thru a rotating shaft. The sequence of thermodynamic processes consists basically of compression, addition of heat in a combustor, and expansion thru a nozzle. The flow of gas is continuous during these thermodynamic changes.

Gas Volumes Produced on Explosion or Detonation of Explosives. The volumes can be determined either theoretically by calculation or experimentally.

Determination of vol by calcn is described in Stetzbacher (Ref 2, pp 68–9), Gorst (Ref 3, p 54), Yaremenco & Svetlov (Ref 4, p 74) and Bandurin & Rukin (Ref 5, p 69).

If formula of deton (or expln) of an individual expln like NG or TNT is known, it is easy to calculate V_o, which is specific volume of gases in liters, produced on expln of 1 kg of expln, calc'd to 0°C & 760 mm with water vapor.
For example, for NG Stettbacher (Ref 1) gives:

\[ 4C_2H_4(ONO_2)_2 = 12CO_2 + 10H_2O(vapor) + 6N_2 + O_2 \]

\[ 4 \times 227.06 \times (12 + 10 + 6 + 1) \times 22 \times 412 \]

\[ 908.24 = 649.95 \text{ liters or } 715.6 \text{ liters for } 1 \text{ kg} \]

Value, \( V_0 \), for NG given in Ref 4, p 75 is

716 liters/kg

For calc of volume for water liquid if vol of water gas is known, first calculate the volume at 100°C according to \( V_{100} = V_T (373^\circ \text{K}/T) \) where \( V_T \) is the known volume at temp T (°K). Then divide \( V_{100} \) by 1672 (which is a combination of the shrinkage factor of 1603 for steam at 100°C going to water at 100°C, and of the shrinkage factor of 1.043 for water at 100°C going to water at 0°C). The correction for steam being non-ideal is minor.

Volume, \( V_t \), at temperature, \( T \), produced on expln can be called by Gay-Lussac’s Law, known in the US as Charle’s Law, also called Dalton’s Law:

\[ V_t = \frac{V_0 (273 + T)}{273} = \frac{273}{273} = 715.6 \times (273 + 4215) = 11751 \text{ liters/kg} \]

If \( V_0 \) for TNT at 0° & 760mm Hg is 740.6 liters/kg, it equals 9015 liters at its temp of decon 3050°C (Ref 2, p 69).

If comp of the expl mixture is known and its equation of expln can be derived, calc of specific volume \( V_0 \) can be done in the same manner as described above.

For example, Russian Ammonit No 6 containing AN 79 & TNT 21% (Ref 4, p 68) can be written as \( C_{6.5}H_{14.1}O_{5.1}N_{2.8} \) and its gases of detonation: \( 6.5CO_2 + 22.1H_2O + 11.3N_2 \). This gives: \( V_0 = 22.4(6.5 + 22.1 + 11.3) = 893.6 \text{ liters/kg} \) (Ref 4, p 74).

If comp of gases produced on expln of an expl mix is unknown, the gases must be removed from the apparatus like Bichel Bomb or Croushaw-Jones Apparatus (both described in Ref 1, pp 84–95), collected in a gasometer and then analyzed by one of the methods listed here under “Gas Analysis”, like that of Orsat.

The device used in Russia for det of volume of gases is the vertical bomb of Dolgov. Its description and procedure are described in Ref 4, p 75. Interior capacity of these bombs is between 15.5 and 50 liters.

The values of \( V_0 \) experimentally detd in Dolgov’s Bomb and listed in Ref 4, p 76 are reproduced here in Table G8.

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Density g/cc</th>
<th>H_2O liq</th>
<th>H_2O gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trottol (TNT)</td>
<td>1.5</td>
<td>610</td>
<td>750</td>
</tr>
<tr>
<td>Tetrtil (Tetryl)</td>
<td>1.55</td>
<td>620</td>
<td>740</td>
</tr>
<tr>
<td>Gheksoghen (RDX)</td>
<td>1.5</td>
<td>700</td>
<td>890</td>
</tr>
<tr>
<td>TEN (PETN)</td>
<td>1.65</td>
<td>550</td>
<td>790</td>
</tr>
<tr>
<td>Ammonit No 6</td>
<td>1.3</td>
<td>430</td>
<td>890</td>
</tr>
<tr>
<td>(AN 79 &amp; TNT 21%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that volume of gases detd by calc of Ammonit No 6 was 893.6 liters/kg with H_2O gas (Ref 4, p 74) and for TNT as reported by Stettbacher” (Ref 2, p 69) was 740.6 liters/kg.

Following values for \( V_0 \) are given in Ref 5:

- 71 – NG 716.8; p 72 RDX 922.6; p 72 NC
- [C_{24}H_{29}(ONO_2)_{11}] 862.3; p 73 MF 236.12;
- p 74 Blasting Gelatin 716.8; and p 74 PA 784 liters/kg

Experimental Procedure for Determination of Volume of Gases as Practiced at Bureau of Mines. The method described below is used as a permissibility and suitability test of mining expls. For this purpose a 200g chge of the expl and its proportional amt of the original wrapper, as found for a 1½-inch diam. cartridge, is fired in Bichel App No 1. The method followed in prep and firing the chge is the same as that employed in making the dem of the pressure described here under "Gas Pressures Developed on Explosion and Detonation of Explosives". It was required, however, that the Bourdon type gage be substituted for the regular piston indicator mechanism. The Bourdon gage was connected to the chamber of the bomb after the shot was fired. Before firing the chge, the bomb was evacuated until a vacuum of 5025mm was obt'd. The vacuum data used were the differences betw the barometer reading for the atm and the manometer reading for the gage. In order that the operator could be assured of obtg vacuum and that there were no clogged lines, the valve connection for the pressure gage on top of the bomb remained open until
after the vacuum pump had been started and air was sucking thru the valve. The chge was fired by means of a No 6 electric detonator imbedded in the chge within the bomb. Five minutes after the shot was fired the stopcock which intervenes betw the bomb and the Bourdon gage was opened and the pressure noted. When the gage reading was obt the gaseous products within the bomb had cooled down to approx room temp. Then the volume of gases and vapors at 0°C and at pressure of 760mm Hg was calcd from the data obt, which comprise bomb temp, bomb pressure, barometric pressure and volume of the bomb (approx 15 liters)

_Crawshaw-Jones Apparatus._ It was recognized that the Bichel apparatus possesses several defects, the chief one being that the conditions under which the expls take place in a Bichel bomb differ from the conditions under which the expls are fired in actual mining operations. This difference lies chiefly in the following facts: In mining, the chge of expl is confined closely within the borehole by stemming, and, when the chge is fired, the products of expln are liberated, thru broken down coal or rock, promptly into atmosphere, where they are free to expand rapidly to an unlimited extent and, therefore, to cool quickly. In the Bichel bomb, however, the chge of expl is practically unconfined when fired, but its expln products are confined within the walls of the bomb where they cool down with relative slowness. Secondary reactions take place, meanwhile, betw the components of the primary expln products, with the result that the cooled products recovered may differ from those produced by the reactions which took place in the expl during the expln and those liberated by the expln in actual mining practice

With a view toward correcting these errors and making laboratory practice conform to field practice, so far as possible, J.E. Crawshaw and J.W. Jones devised and developed the Crawshaw-Jones Apparatus at the Explosive Experiment Station, Bruceton, Pennsylvania.

Since the C-J apparatus is not described in the literature and since _BurMiner's Bull_ (Ref 1) is out of print we are including here the description given on pp 97–99 of _Ref 1_.

This apparatus is illustrated in Fig G13. For convenience in description, the sketch may be regarded as divided into two principal parts.

Part 1 consists of:

1) Firing cannon, _a_, a forged-steel cylinder 24 inches in diam and 36 inches long with a borehole 2½ inches in diam and 2½ inches long. It is mounted on a movable truck so that it can be moved to and from pipe _b_ for loading the cannon and cleaning chamber _b_.

2) An expansion chamber, _b_, which is a piece of 8-inch extra-strong lapwelded wrought-iron pipe 10 feet long, flanged at each end and

_Taking Samples of Gases and Vapors for Chemical Analysis._ One half-hour after the shot was fired a sample of the gases and vapors was taken thru the valve in which the air pump was attached. The gases were allowed to escape from the bomb slowly by cracking the valve, and a 200cc sample was thereby collected over mercury of the aspirator during the entire time of the escape of the gases. In collecting a sample the mercury of the aspirator was allowed to run out, and the gases and vapors that followed were drawn off until the pressure within the bomb was reduced to that of the atmosphere; therefore, the sample of gases and vapors taken was a differential one.

The liquid and solid products of the reaction were collected and measured after the head of the cylinder had been removed, the liquid products being drawn off into a measuring vessel and the solid products scraped out and weighed. Since secondary reactions might take place as soon as the air struck the products, the material collected might not be identical with that immediately resulting from the reaction; however, no better method appears to have been devised.

The gaseous products were analyzed by means of an Orsat apparatus and then entered upon special form under "Analysis of Gases" (Volume per cent). An example of calcn is given in _Ref 1_, p 94. See also "Gases Produced on Explosion of Detonation."
FIG G13 SKETCH SHOWING DETAILS OF CONSTRUCTION OF CRAWSHAW-JONES APPARATUS AND ACCESSORIES

bolted to the cannon and counterweight c by twelve 7/8-inch steel bolts

3) Counterweight c of the same dimensions as the cannon a, to stabilize the apparatus when the explosive is fired from a

Part 2 consists of the pressure-equalizing, mixing, and sampling devices. By partly evacuating equalizing chamber d before firing at a the pressure in expansion chamber b can be released into it immediately after a shot with a resultant pressure in the whole apparatus of slightly more or slightly less than atmospheric, which lessens any tendency to leak during the cooling and mixing of the gases. Pump e is used to evacuate equalizing chamber d, which is used for mixing the gases and sweeping out the entire apparatus after each test.

Charges of 150 to 200 grams are used in each test. This charge of explosive gives detonation products of a good degree of concentration and does not produce excessive pressures within the apparatus at the instant of detonation, and the effects of the products from the detonator can be disregarded. Moreover, charges of this size can be packed in the borehole in the same manner for each shot.

**Test Procedure.** The procedure of testing is as follows:

The stud bolts which hold the firing cannon a to pipe b are unscrewed, and the cannon is rolled back out of the way. A scraper is used to clean the pipe of stemming material and foreign material from the previous trial, and the first 3 feet of the pipe next to the firing cannon is wiped out thoroughly. The borehole of the firing cannon is then cleaned of residue from the previous trial, and the explosive and electric detonator are charged in the cannon according to the desired method

Stemming is then inserted in the borehole and tamped firmly against the expl. The ends of the legs of the electric detonator are then cut off at the proper length, and one leg is fastened to a screw in the face of the cannon.

When the apparatus has been cleared of gases from the previous trial the cannon is rolled close to the pipe and the other leg from the electric detonator is joined to firing plug g. The cannon is then rolled against pipe b and made gastight by screwing down the stud bolts. Valves 2, 3, 4, 7, 8 and 10 are closed and valves 5, 6 and 9 (tube v being disconnected from 9) opened; the pump is then started, thus evacuating the air from chamber d. When a sufficient vacuum is produced in chamber d to take care of the
volume of gas it is estimated will be liberated by the expl, valves 5 & 9 are closed, the pump is stopped, and valve 11 is closed. The charge of expl is detonated by means of the electric detonator fired by the aid of a push-down battery, and the gases liberated into pipe b by the expl are quickly released into the chamber d by opening valves 2 & 3. Valves 5, 10 & 11 are then opened and pump e, which circulates the gases thru the pipe, equalizing chamber, and pipe connections, is operated. Tests have shown that five mins of circulation is sufficient to mix the gases thoroughly. At the end of five mins the pump is stopped, and the pressures on manometer b and u and the temp on thermometers y and w are read. The pump is then operated five mins more and the temp and pressure readings again noted. These last values are used in the calculations of the results.

Sampling gas. — A sample of the gas is then withdrawn for analysis by means of sampling tube p and mercury leveling bottle r. Cock o is opened to connect the sampling tube with the outside air. The cocks on the sampling tubes are opened, and mercury-leveling bulb r is raised, thus causing the tube to fill with mercury. When the mercury reaches cock o the cock is turned to connect with the pipe leading to the interior of the apparatus. The mercury-leveling bulb is then lowered, and thus a sample of gas is drawn out from the drum. This sample is discarded because it contains air from the connection, and a second air-free sample is withdrawn in the same manner.

Analysis of gas. — The sample of gas thus obtb is then analyzed for carbon dioxide, oxygen, carbon monoxide, hydrogen, and methane on a BurMines Orsat apparatus. Oxides of nitrogen are tested for in a separate sample. The nitrogen is detd by difference. If the volume of the entire apparatus, the temp and pressure of the gas, and its compn as given by analysis are known, the amounts of the different constituents produced by the explosive can be computed.

Accessories to apparatus. — Orifice j was placed in the circuit to indicate on flow meter i how the pump is operating in circulating the gases thru the apparatus. High rates of flow of gas are shown by large differences of level in the two columns of liquids in the flow meter.

Pump e is of the friction-plate type and can be used for either vacuum or pressure. It is best to operate the pump with the minimum amount of lubricant that gives the vacuum desired, so that equilibrium is quickly obtb betw the gases and oil with very little effect on the gases. “Nujol”, a medicinal lubricant, is used for the pump. This oil has a high fl p and has proved satisfactory for this work. A low fl p oil is undesirable because it gives off volatile constituents that will contaminate the gases from the expls. A dust trap was found necessary to prevent stemming and soil dust from getting into the drum and pump of the apparatus. It should be cleaned out after every 15 to 20 trials and the packing replaced with fresh glass wool.

An attempt was made to put a thermometer well into pipe b for recording the temp of the gases, but in every case the wells were broken off after one or two trials by the force of the explosions. Temp readings of the gas in the pipe were obtb by placing a thermometer along the bottom of the pipe, then placing a copper shield over the Hg bulb in contact with the pipe, and covering it with insulating material. The thermometer responded very quickly to a change of temp of the pipe. Temps were recorded in two places because, 10 mins after shooting, the pipe was 1.5° to 2.0° higher in temp than other parts of the apparatus. The two values were averaged.

The following typical example will illustrate the procedure for the calculation of test data:
Table G9
Sample Calculation

| Volume of pressure apparatus including all parts | 179.3 liters |
| Weight of explosives used | 162.1 grams |
| Average temperature of cooled gases | +5.0 °C |
| Average manometer readings | -19 mm |
| Volume of space occupied by tamping in borehole | 0.5 liter |
| Corrected volume | 178.8 liters |
| Barometric pressure | 734 mm of Hg |
| Corrected pressure=734-19 | 715 mm of Hg |
| Corrected temp=273+5 | 278 °C |
| Volume corrected to 0°C & 760mm pressure | 165.2 liters |

Gas Warfare Agents. See under CHEMICAL AGENTS OR CHEMICAL WARFARE AGENTS in Vol 2 of Encycl, pp C165-R to C171-L.

Gas, Water and Carburetted Water Gas.
Water-gas is made by passing steam thru a bed of incandescent coke or other fuel. The temp of such a fire is 1400°C (2552°F). Betw the temps of 1400° and 1000° (1832°F) the reaction \( \text{H}_2\text{O} + \text{C} = \text{CO} + \text{H}_2 \) which is endothermic, takes place, but if the temp drops below 1000°, the steam reacts to form \( \text{CO}_2 + 2\text{H}_2\text{O} + \text{C} = \text{CO}_2 + 2\text{H}_2 \) which is not desired because \( \text{CO}_2 \) has no caloric value. In order not to allow the temp to drop below 1000°, the steam is periodically stopped, and the fire is brought back to normal high of 1400° by an air blast. Coke is consumed during air-blasting, evolving not only CO but also \( \text{CO}_2 \).

A detailed description of manufg water gas is given in Riegel (Ref 1, pp 271-72) together with Fig 99 representing a cross-section thru a water-gas plant.

For many purposes, water gas is used as such, but for sale to municipalities, it is usually enriched with oil gas produced in a separate vessel forming part of the system. Such enriched gas is known as carburetted water gas. Its manuf is described on p 273 and purification on p 274 of Ref 1.

Riegel gives (Ref 1, p 271) the comps of straight enriched water gases shown here in Table G11.

Table G10
Composition of gases in apparatus after test

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Per cent by volume</th>
<th>Gas per 100 grams of explosive, liters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>11.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Oxygen</td>
<td>12.5</td>
<td>12.75</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>3.2</td>
<td>3.25</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2.0</td>
<td>2.05</td>
</tr>
<tr>
<td>Methane</td>
<td>1.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>69.7</td>
<td>71.00</td>
</tr>
</tbody>
</table>

The number of liters of gas is obt by multiplying the percentages of gases given by analysis by the liters of gas in the apparatus and dividing by the weight of expl used.

Refs: 1) USBurMinesBull 346(1931), 91-5 2) Stettbacher (1933), 68-9 3) Gorst (1957), 54 4) Yaremko & Svedov (1957), 74 5) Bandurin & Rukin (1959), 69 6) Gorst (1972) (New edn of Ref 3), pp 58-9 (Full tides of these Refs are given under "Gas Pressures Developed on Explosion or Detonation of Explosives", Refs 1, 2, 4, 5, 6 & 7)

Table G11

<table>
<thead>
<tr>
<th>Components</th>
<th>Water Gas Straight</th>
<th>Water Gas Enriched by Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>3.7</td>
<td>4.25</td>
</tr>
<tr>
<td>Ethylene or other illuminants</td>
<td>-</td>
<td>10.33</td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.5</td>
<td>0.71</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>42.3</td>
<td>31.60</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>47.9</td>
<td>35.38</td>
</tr>
<tr>
<td>Methane</td>
<td>0.6</td>
<td>12.40</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>3.4</td>
<td>5.33</td>
</tr>
<tr>
<td>Total Combustibles</td>
<td>90.8</td>
<td>89.71</td>
</tr>
<tr>
<td>BTU per cu ft</td>
<td>299</td>
<td>574</td>
</tr>
</tbody>
</table>

Gothurst (Poudre de). Accdg to Daniel (Ref), one of the British powders manufd since 1895 by the Roburite Explosives Co, Ltd at Gothurst consisted of AN B4.40, DNB (Dinitrobenzene) 15.52 & moisture 0.08%
Ref: Daniel (1902), 323

Gothurst Powder. Accdg to Marshall (Ref 1), it is a British permitted expl contg AN 51, K nitrate 6, TNT 18 & NaCl 25%. Its strength by swing of Ballistic Pendulum is 2.41 inches, compared with 3.27 inches for British Standard Gelignite (60% NG)
A slightly different compn is given by Taylor: (Ref 2): AN 49.0-52.0, K nitrate 5.0-7.0, TNT 16.5-18.5 & NaCl 24.0-26.0%; density 1.10, strength (% of Blasting Gelatin) 53. It was a powdery material used in moderately hard ripping and blasting in hard coal
Note: When strength (power) of Amer AN Dynamos is measured, it is compared to American Straight Dynamite contg 40% NG. Its Ballistic Pendulum Swing is 2.7 to 3.1 inches

Gothurst Powder (Sheathed). See Vol 3 of Encycl, Table, p C452, bottom

Gattermann, Ludwig (1860-1920). A German organic chemist, noted for laboratory methods
Ref: Hackh's Dictr (1944), 571-L

Gatling Machine Gun or Organ-Grinding Machine Gun. One of the first successful machine guns. It was invented in 1862 by an American R.J. Gatling, and used to some extent in the American Civil War (1861-1865), Franco-Prussian War (1870-1871) and Spanish-American War (1898)
The weapon consisted of ten barrels; it weighed 90 pounds and could fire up to 1 000 shots per minute

Goubitza, pronounced Gowbitza. Russian for Howitzer

Gauss, Karl Friedrich (1777-1855). A German mathematician who developed the conception of the three fundamental units: length, mass and time
In his honor was named gauss, the unit of intensity of a magnetic field (field strength): A magnetic field which exerts a force of one dyne on a unit magnetic pole: 1 gauss (EMU)= 0.3 x 10^-10 esu. For small measurements: 1 y= 0.00001 gauss
Ref: Hackh's Dictr (1944), 371-L

Gautier Receiver. A glass apparatus for collecting different samples from the same condenser during distillation in vacuum
Ref: Hackh's Dictr (1944), 371-L

Gay-Lussac, Josef-Louis (1778-1850). A French chemist and physicist noted for the formulation of the gas laws. He also isolated boron and invented volumetric methods, many scientific and industrial devices (like hydrometer used for alcoholic liquid and tower used in the chamber process for the manuf of sulfuric acid to absorb the oxides of nitrogen in the crude acid produced)
Gay-Lussac Acid. The sulfuric acid–nitrogen oxides mixture which is the product of the Gay-Lussac tower in the chamber process for manuf of sulfuric acid. The sulfuric acid strength of Gay-Lussac acid is 60°Bé and nitrogen oxides content (calc’d as N₂O₅) 1–2% Ref: CondChemDict (1961), 529-L; (1971), not found

Geissler, Heinrich (1814–1879). A Ger physicist who determined the coefficient of expansion of water and invented the so-called Geissler Tube. It is a partly evacuated glass tube used in the study of electric discharges thru gases and for spectroscopic examinations Ref: Hackh’s Dict (1944), p 372-L

Gel or Jel. A jelly or a solid phase of a colloidal soln, as opposed to sol, the liquid phase. Gel is actually a colloidal soln of a liquid (such as acetone, NG, NGc) in a solid (such as NC) Ref: Hackh’s Dict (1944), 372-L

Gels for Flame Throwers, such as “Gelgas” or “Jellied Gasoline” and “Napalm” are described in this Vol, under “Flame Throwers Liquids and Gels” p F56

Geiger-Müller Counter or Tube. A common form of nuclear radiation detector, also serving for measuring the intensity of radiation such as of X-rays, γ-rays, etc. It is particularly suitable for monochromatic beams. The device usually consists of a tubular cathode with a coaxial center wire anode, filled with a gas (such as argon plus oxygen or argon plus hydrogen) at less than atm pressure. When a high voltage is impressed across the electrodes, ionizing radiation traversing the tube gives rise to conductivity pulses which may be electrically amplified and registered. Each ionizing event gives rise to one pulse, and the counter tube with its associated electrical circuitry “counts” the number of individual ionizing radiations Refs: 1) Hackh’s Dict (1944), pp 371-R & 371-L (Fig on p 372) 2) H.R. Clauser, “Practical Radiography for Industry”, Reinbold, NY (1952), p 13 3) CondChemDict (1961), p 529-R 4) Kirk & Othmer, Vol 17 (1968), p 72

Gelammites. Trademark of Hercules Powder Co, Inc for high AN expls, introduced in 1927, which are cohesive, but only slightly plastic (semigelatinous). They are of relatively high weight strength of 65% and very good water-resistance. They can replace the gelatins, except in the most severe conditions. Used in underground mining, quarrying, construction, and general blasting. Compositions are not given Refs: 1) J.J. Berliner & Staff, “Explosives”, Pamphlet, NY (1953), pp 6 & 10 2) CondChemDict (1961), p 529-R; (1971), not found

Gelammonite No 1, Antifrost. Brit permitt expl described as Antifrost Gelammonite No 1 in Vol 1, p A468-L

Gelatin and Glue.

Gelatin, Animal is a nearly colorless, tasteless, odorless, transparent, brittle, vitreous solid, consisting of a mixture of soluble proteins of high average molecular weight. The commercial product contains 9–12%
moisture and its density is 1.3 to 1.4. Gelatin possesses the property to form a gel (jelly) in aqueous media below 35–40°. On digestion, it yields various amino-acids.

Gelatin is obtained by heating collagen (the major intercellular protein constituent of the entire connective tissue of animal skins and bones) with water or dilute hydrochloric acid. Its production differs from that of glue in that the raw materials are selected, cleaned and treated with especial care, so that the resulting product is practically colorless.

It is insol in cold w; swells in warm w (35–40°); sol in hot w, AcOH and a hot mixture of glycerin and water.

Besides its use in foods, candies, photographic films, adhesives, gelatin capsules etc., it has been used as a binder in some explosive and pyrotechnic compositions Glue, Animal (or Common Glue). An impure or degraded form of gelatin is obt by action of heat and water on protein animal tissues of bones, hides or horns. It absorbs cold water with much swelling and dissolves in hot w, the soln solidifying to a jelly on cooling. Used in adhesives, gummed tapes and can be used as a binder for some expl & pyrotechnic compns.

Fish Glue is obt by heating with w the heads, fins and tails. It has weak jellying props and is generally made into liquid glue. For this a fish or common glue is treated with acetic, nitric or hydrochloric acid. It has no gelatinizing props but retains the adhesiveness. Casein Glue is an adhesive prep by dissolving casein in alkaline solns. It can be used cold. Chrome Glue is an insol product prep by mixing common glue with Amm or K dichromate or with chrome alum. It is used as a grass cement and waterproofing material. Glycerin Glue is a flexible elastic which dissolves in glycerin.

Japanese Gelatin. See Agar-Agar in Vol 1 of Encyc, p A110-L.


GELATIN (Explosive). Amer name for Gelatin Dynamite; Brit Gelatine Dynamite; Ger Gelatine Dynamit; Fr Gelatine dynamite; Ital Gelatina dinamita or Gelatina explosive; and Russ Zhelatin dinamit. Gelatin was invented by Swedish scientist Nobel in 1875 (BritP 4179) (Ref 3). It was a blend of NG, CC (Collodion Cotton) & 1% chalk. Its consistency was similar to Pan gum rubber and it was practically impervious to water. The strength was taken as 100%. This expn is now known as Blasting Gelatin (qv) and the formulation comprising NG 98 & CC 8% is one of the Brit "standard" gelatinized explosives. Later formulations cont other ingredients, such as WM (woodmeal) or inorganic nitrates, known in the US as "dope". Such expls were softer than Blasting Gelatin because they contained less CC. Two of such gelatinized expls were Brit "standards", namely: Gelatine Dynamite — NG 75, CC 5, WM 5 & K nitrate 15% and Gelignite — NG 60, CC 4, WM 8 & K nitrate 28% (Ref 2). Such expls can be called "Straight Gelatins".

When a part of NG is replaced with NGc (Nitroglycerol), the so-called LF (Low-Freezing) Gelatins are obt. When part of NG (and of NGc) is replaced with AN (Ammonium Nitrate) in such quantities as to produce the same strength as before the replacement, the expl becomes Extra LF Gelatin (Ref 5).

The gelatinization of Nobel's Gelatins was facilitated either by warming to ca 60° or by adding volatile solvent, such as acetone, in cold. Later it was discovered that gelatinization is greatly facilitated not only by the addn of volatile solvents, but also by the addn of small quantities (sometimes as little as 0.1–1.0%) of substances, such as nitrated compds of benzene, toluene or xylene; urethanes, anilides, substituted ureas, etc. With these compds, gelatinization occurs in the cold. The soft gelatinous and semigelatinous
expls prep'd in this manner, known as plastic explosives are used as "commercial explosives" and also as "military demolition explosives" (Refs 1 & 3)

The important discovery of Nobel revolutionized the mining expls industry because Gelatins were much more powerful than Guhr Dynamite, previously invented, and they practically did not exude. They were particularly suitable for blasting hard rocks.

Stettbacher (Ref 4) prep'd (1928–1929) a series of Gelatins consisting of PETN, NG and CollodCotton. These expls were called Gelatine-Penthrinit (See in this Vol)(Ref 4)

A series of new plastic expls based on RDX were prep'd during WWII in the USA. They were designated as Composition C, C-2, C-3 & C-4 (See in Vol 3, pp C484-L to C486-L)


Gelatin, 100%. DuPont & Co name for their Blasting Gelatin

Gelatina. Italian and Spanish name for Gelatin

Gelatina 808. Ital nonpermismissible expl listed in Vol 3, p C440-L

Gelatino-dinomite N.O. Ital nonpermismissible expl listed in Vol 3 of Encycl, p C440-L and in Giua, Trattato, VI(1), (1959), p 344

Gelatina explosiva. Ital for Blasting Gelatin. Same as Gelatina gomma

Gelatina explosiva. Span for Blasting Gelatin

Gelatina explosiva de collodión. Span Gelatin consisting of NG & Collodion Cotton exploding accdg to the equation:

\[ 31C_3H_5(NO_2)_2 + C_2H_2(NO_2)_3O_{11} = 177CO_2 + 143H_2O + 81N_2 \]

Ref: Vivas, Feigenspan & Ladreda, Vol 2 (1946), p 391

Gelatina explosiva de fulmicotón. Span Gelatin consisting of NG & Gunpowder exploding accdg to the equation:

\[ 41C_3H_5(NO_2)_2 + C_2H_2(NO_2)_3O_{11} = 147CO_2 + 117H_2O + 67N_2 \]

Ref: Vivas, Feigenspan & Ladreda, Vol 2 (1946), p 391

Gelatina explosiva de guerra. Span name for the military expl invented in 1878 in Austria (See in Vol 5 under DYNAMITE, Class X, p D1610-L). It was used during Spanish-America War (1898) for loading projectiles fired from pneumatic cannons. Its compn: NG 86.40, NC 9.60 & camphor 4.00% was given by Vivas, Feigenspan & Ladreda, Vol 2, p 393. Russians used a similar expl contg 3% camphor for loading (during WWI) trench mortar shells, while Italians used the expl contg 5% of camphor (See Vol 5, p D1610-L)

Gelatina gomma. Ital for Blasting Gelatin contg NG 92 & NC 8%

Ref: Belgrano (1952), pp 85–6

Gélatine (Fr): NG 57, Collod Cotton 3, K or Na nitrate 34, sawdust 4, cereal flour 1.8 & red ochre (colorant) 0.2%

Ref: Pepin Lehalleur (1935), p 334

Gélatines (Belg & Fr). Daniel (Ref) gives comps of older Belgian and French Gélatines contg % NG: 86, 84, 83, 82, 74, 70, 69.5, 67, 50, 45, 43 and 25

Ref: Daniel (1902), pp 328–29
Gélatines, French (Low-Freezing). See Vol 5, p D1591, Table I, under DYNAMITE

Gelatine, Blasting (Brit): NG 63.4, Collod Cotton 1.6, K or Na nitrate 26.75, sawdust 8.40 & Ca carbonate 0.35%
Ref: Pepin Lehalleur (1935), p 335

Gelatine, Blasting (Low-Freezing) (Ger & Swiss). See Vol 5, p D1591, Table I, under DYNAMITE

Gelatine-Aldorfits. They are Swiss plastic expls contg NG, manufd by the Schweizerische Sprengstoff-Fabrik AG, Dottikon. Compo of one of them was: NG with NGc 22, Collodion Cotton 1.5, liq DNT with TNT 13 & AN 63.5%. Its props were: Trauzl Test value 4000cc for 10g sample (vs 310 for TNT); Brisanse (by copper cylinder compression) 3.25mm (vs 2.86mm for TNT); detonation velocity 6000m/sec at d 1.49 (vs 6970 for TNT at d 1.60); impact sensitivity with a 3kg weight 35cm (vs 45 for TNT); and explosion temp at the rate of 20° per minute 185°.

There were also manufd Gelatine Aldorfits B & C and Gelatine Aldorfit with 20% Al
Ref: 1) A. Stebbacher, "Spreng- und Schießstoffe", Rascher Verlag, Zürich (1948) 2) Dr A. Stebbacher, Private Communication, Zürich, Dec 14, 1953

Gélatine à l'ammoniaque A ou n° 2: A Belg explosif de sûreté: NG 30, Collod Cotton 3 & AN 67%
Ref: Gody (1907), pp 702 & 712

Gelatine-Astralit (Ger). A plastic low-freezing Dynamite contg DNCH with NG 30, DNT+TNT 10, AN+Na nitrate+woodmeal 60%. Its density 1.45; lead block expansion 400cc; lead block crushing 18mm; velocity of detonation 7300 m/sec; can be initiated by No 3 cap
Ref: 1) Naoum, NG (1928), 379 2) PATR 2510 (1958), p Ger 66-L

Gelatine B, Blasting (Brit). NG 43.9, Collod Cotton 1.1, K or Na nitrate 41.25, sawdust
13.20 & Ca carbonate 0.35%
Ref: Pepin Lehalleur (1935), p 335

Gelatin Blasting Explosive of J. Taylor et al, BritP 670453 (1952) & CA 46, 10625 (1952): 80/20 mixt NG/NGc 57.5, NC 2.4, woodmeal 10.0, Na nitrate 24.8, finely milled barytes 5.0 & chalk 0.5%. Claimed to be suitable for work under a hydrostatic pressure of 40 atm. See also USP 2677605 (1954)

Another expl of J. Taylor et al, BritP 670454(1952) & CA 46, 10625(1952), was claimed to be suitable for work in seismic prospecting and for well blasting. It consisted of an 80/20 mixt of NG/NGc 57.5, NC 2.5, peanut meal (deproteinized & de-oiled, ground) 13, Na nitrate 26.4, chalk 0.3 & diammoniumphosphate 0.3%

Gelatine-Carbonit (Ger). Several varieties exist as can be seen from Table G14

<table>
<thead>
<tr>
<th>Ingredients and some properties</th>
<th>Gelatine-Carbonite</th>
<th>Gelatine-Carbonite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am nitrate</td>
<td>31.0</td>
<td>46.4</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>4.4</td>
<td>7.0</td>
</tr>
<tr>
<td>K nitrate</td>
<td>-</td>
<td>5.1</td>
</tr>
<tr>
<td>NG (mixed with collod cotton)</td>
<td>23.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Glycerin plus gelatin</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Na chloride</td>
<td>24.0</td>
<td>27.5</td>
</tr>
<tr>
<td>Vegetable meal</td>
<td>10.0</td>
<td>4.0</td>
</tr>
<tr>
<td>TNT</td>
<td>3.0</td>
<td>-</td>
</tr>
<tr>
<td>Ultrasilicone</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oxygen Balance,%</td>
<td>-13.1</td>
<td>+2.2</td>
</tr>
<tr>
<td>Trauzl Test, cc</td>
<td>220</td>
<td>200</td>
</tr>
<tr>
<td>Vel of Detonation, m/sec</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Ref: 1) Naoum, NG (1928), 407, 411 & 441 2) PATR 2510 (1958), p Ger 66-R
Gelatine-Carbonite, listed in Gody (Ref), contd: NG 27.0, NC 0.7, glue of gelatine-glycerin 6.5, AN 29.0, Na nitrate 22.8 & Amm chloride 14.0%
Ref: Gody (1907), p 713

Gelatine-Cheddit (Ger). Gelatinous expls based on chlorates, such as Na chlorate 70 & Collodion Cotton gelatinized with NG. They might serve as substitute Dynamites
Refs: 1) Naoum, NG (1929), 353 2) PATR 2510 (1958), p Ger 66

Gelatine-Cheddit (Swiss). Plastic chlorate expls invented in 1911 by C. Rubins and then manufd by the Schweizerische Sprengstoff AG Cheddit and Dynamit. These expls are stable and do not harden in storage. The prepn and compn of one of the earliest formulations is given by Steetbacher in Ref 1. In Ref 2, p 87 the compn of newer Gelatine-Cheddit is given as follows: Na chlorate 79 (coated with a liq mixt of castor oil 5, liq DNT 2 & TNT 14 parts, preheated to ca 40°). Some Collodion Cotton could be incorporated. Its props are given in Ref 2 on p 104 as follows: max density 1.97, practical 1.8–1.9; specific volume (vol of gases at NTP) 340 l/kg; rest of expln (at const vol, water vapor) 1100 kcal/kg (263 kcall/l); temp of expln 3500°; max deton vel 3800 m/sec; impact sensitivity with 2 kg weight 120 cm vs 30 cm for TNT; and Trauzl test value 257 cc for a 10 g sample vs 310 for TNT at density 1.55

Gelatine-Dahmenit (Ger). A type of low-freezing gelatinous Dynamite manufd for a long time by the Rummenohl Plant of the Westdeutsche Sprengstoffwerke of Dortmund. Two formulations are listed in Table G15

Table G15

<table>
<thead>
<tr>
<th>Ingredients and some properties</th>
<th>Gelatin-Dahmeniten A</th>
<th>Gelatin-Dahmeniten B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dinitroglycerin</td>
<td>27.4</td>
<td>27.4</td>
</tr>
<tr>
<td>Collodion cotton</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Nitrotoluene</td>
<td>4.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>32.0</td>
<td>32.0</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>5.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Alkali chloride</td>
<td>27.5</td>
<td>30.0</td>
</tr>
<tr>
<td>Trauzl Test, cc</td>
<td>233</td>
<td>205</td>
</tr>
<tr>
<td>Charge limit iniredamp, grams</td>
<td>350</td>
<td>700</td>
</tr>
</tbody>
</table>

Ref: 1) Naoum, NG (1928), 419 2) PATR 2510 (1958), p Ger 66

Gelatin Detonating Explosive Containing Chopped Straw. Cereal straw cut to 1/3–1 cm length and 0.3–1.3 mm width, and having bulk density of 0.21 under 25 psi does not impair the sensitivity or vel of a gelatin dynamite at the 9.5% level on storage at 35° as it has minimal absorption of the liq expl ingredient
Ref: C.R.S. Harries & J.C. Homel, Brit P 578885 (1946) & CA 41, 1842 (1947)

Gelatine Diaspon. See Diaspon Gelatine in Vol 5 of Encycl. p D1533-L

Gelatine-Donarit (Ger). A type of gelatinous industrial expl which contd DNCI=NGC 30, AN 50 & other ingredients 20% (Refs 1 & 2). Another gelatinous Donarit is described in Ref 2, p Ger 38. It contains NGC 22, Collodion Cotton 1, AN 55, Na nitrate 10, TNT 5, DNT (liquid) 6, woodmeal 0.8 & dye (caput mortuum)

Note: DNCI = Dinitrochlorohydrazin; NGC = Nitroglycol
Refs: 1) F. Weichelt, "Sprengtechnik", Marhold, Halle/Saale (1953), 37 & 375 2) PATR 2510 (1958), pp Ger 38 & Ger 66
Gelatin Dynamites (Amer.). Compns of 20, 30, 40, 50, 60, 80 and 100% are listed on p D1600, Table V, under DYNAMITE in Vol 5 of Encycl

Gelatine Dynamites (Brit.). Three "standard" gelatinized explosives: "Blasting Gelatin", "Gelatine Dynamite" and "Gelignite" are described here under GELATIN(Explosive) (Ref 1, p 104 & Ref 2, p 345)

When the supply of K nitrate became scarce during WWI it was replaced with Na nitrate in British "standard" Gelatine Dynamite and Gelignite (Ref 1, p 105). Giua (Ref 3) gives the following compn: NG 71, Collod Cotton 6, K nitrate 18 & woodflour 5% for one of the Brit Gelatine-Dynamites Refs: 1) Barnett (1919), pp 104 & 105 2) Davis (1943), p 345 3) Giua, Trattato 6(1) (1959), p 344

Gelatine-Dynamites (French). Accdg to Giua (Ref), they include: Gelatine-Dynamite A: NG 64, Collod Cotton 3, Na nitrate 24 & woodflour 9% Gelatine-Dynamite B-potasse: NG 57.5, Collod Cotton 2.5, K nitrate 32.0 & woodflour 8% Gelatine-Dynamite C-soude: NG 57, Collod Cotton 3, Na nitrate 34 & woodflour 8% Ref: Giua, Trattato 6(1) (1959), p 344

Gelatins-Dynamits (Ger). A type of gelatinous explosive introduced by Alfred Nobel in 1875. The strongest of these, "Sprenggelatine", contained NG 92 & Collod Cotton 8%. It is described as "Blasting Gelatin" in Vol 2 of Encycl, pp B211-R to B212-L. Other Gelatins prepd by Nobel contained ingredients (such as inorg nitrates, vege-

<table>
<thead>
<tr>
<th>Components and Some Properties</th>
<th>Gelatin-Dynamites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>81%</td>
</tr>
<tr>
<td>NG</td>
<td>75.8</td>
</tr>
<tr>
<td>Collod Cotton</td>
<td>5.2</td>
</tr>
<tr>
<td>Vegetable meal</td>
<td>3.8</td>
</tr>
<tr>
<td>DNT + TNT</td>
<td>-</td>
</tr>
<tr>
<td>K nitrate</td>
<td>15.2</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>-</td>
</tr>
<tr>
<td>Alkali nitrate and/or K perchlorate</td>
<td>-</td>
</tr>
<tr>
<td>Alkali chloride</td>
<td>-</td>
</tr>
<tr>
<td>OB to CO₂</td>
<td>-</td>
</tr>
<tr>
<td>Density</td>
<td>-</td>
</tr>
<tr>
<td>Lead Block Expansion</td>
<td>-</td>
</tr>
<tr>
<td>Lead Block Crushing</td>
<td>-</td>
</tr>
<tr>
<td>Max Velocity of Detonation</td>
<td>-</td>
</tr>
<tr>
<td>Heat of Explosion kcal/Kg(H₂O vapor)</td>
<td>-</td>
</tr>
<tr>
<td>Temp of Explosion, °C</td>
<td>-</td>
</tr>
</tbody>
</table>
table meal, etc) called "Zumischpulver", known in the USA as "dopes"

Get Gelatine-Dynamites may be subdivided into the following groups:
A. Gewöhnliches und Schweregefrierbares – ordinary and difficulty freezing (low-freezing)
B. Phlegmatisiertes, transporticheres – phlegmatized, safe to transport
C. Schlagwetteres oder Wettersicheres – safe in the presence of firedamp(pennissible)

To the A type belong the Blasting Gelatin and the Gelatines shown in Table G16

Any of these expls may be rendered low-freezing by incorporating NGc (Nitroglycerin), DNG (Dinitroglycerin) or DNCIH (Dinitrochlorohydrin). Aromatic nitrocompounds, such as DNT and TNT, can be used for the same purpose

To the B group belong Dynamites in which most of NG is replaced by DNCIH, as for example, in Gelatine-Prospers listed in Table G18, p G52

To the C group belong Dynamites containing small amts of NG and appreciable amts of "cooling" agents, such as alkali chlorides, as for example Gelatin-Dynamite No 4a, listed in Table G16 and Gelatine-Prospert. Dynamites which contain large amts of AN (Ammonium Nitrate) also belong to this group (See Ammongelatine and Gelatine-Prospert)


Gelatine-Dynamits (Ger & Swiss). Formulations No 1, No 2 & No 3 are given on p D1601, Table VI, under DYNAMITE in Vol 5 of Encycl

Gelatin-Dynamite (Japanese). See under Pemissible Explosives in Vol 3, p C454-L

Gelatin-Dynamite Containing Ammonium Nitrate. AN 50, urea 25, Na acetate trihydratre 15 & Na thiosulfate pentahydrate 10 parts are warmed until no solid remains; then 80 parts of this liq is mixed with 20 parts of NG containing 1% sol NC


Gelatin Dynamite Containing Ammonium Nitrate(Japanese). NG 28, NC 1.2, AN 43.3, starch 10, NaCl 20.0, soft wax 0.5 & urea 6% are pressed and wrapped in stick form.


Gelatin-Dynamites of Apache Powder Co, Benson, Arizona. See Vol 5, p D1602, Tables VII & VIII, under DYNAMITE

Gelatin Dynamite for Blasting Under High Liquid Pressure. Consists of blasting dynamite 97 (NG, NC, NaNO₃, wood pulp) and resin-treated comob meal 3%. The latter is 25% heat-hardenable urea- or phenol-formaldehyde resin and is ground to 40 mesh after curing


Gelatin Dynamite Containing Chopped Straw. See Gelatin Detonating Explosive Containing Chopped Straw in this Vol

Gelatin-Dynamite Containing Crystalline Salts. An 80/20 mix of NG/NGc 21 is used to dissolve P-NO₂ Toluene 3 and p-tert-octyl-phenyl diethylphosphate 0.2 parts; gelled with NC 1.1, then mixed with AN 56.9, NaNO₃ 12, oat hush meal 2, waxed woodmeal 0.5, woodmeal 1, sulfur 2, starch 0.5 & chalk 0.3 parts

Refts: H.R. Wright et al, BritP713758 (1954) & CA 49, 3537 (1955); USP 2716056 (1955) & CA 49, 15242 (1955)

Gelatin-Dynamite Containing Glycol Ethers. Improved plasticity and ease of extrusion of
gel dynamites is obtained by incorporation
0.2–0.4% of a polyethylene glycol having at
least 8 carbon atoms together and at least 2
ehtyleneoxy groups together
Re: S. Fordham & J.L. Moilliet, USP
2454643 (1948) & CA 43, 3619 (1949); BritP
586224 (1947) & CA 41, 7120 (1947)

**Gelatin-Dynamite with Improved Plasticity.**
Incorporation of dried vegetable protein or
protein-rich meals, such as soybean, into NG
dynamites increases resistance to NG leak-
age due to sudden or large temperature changes
Re: 1) M. Bonotto, USP 2413946 (1947) &
CA 41, 2246 (1947) 2) S. Fordham et al.,
BritP 586224 (1947) & CA 41, 7120 (1947)
(Inclusion of 0.4% of polyethylene glycol
ether contg at least 8 carbon atoms)

**Gelatin-Dynamites, Low-Freezing.** American
comps of 25, 40 and 60% LF Gelatin Dynam-
ites are listed in Vol 5 of Encycl, p D1592,
Table II, under DYNAMITE

**Gelatine-Dynamits, Low Freezing.** German
LF Gelatine-Dynamits are listed in Vol 5,
p D1591, Table I under DYNAMITE

**Gelatin-Dynamites Containing Nitroglycerin
Fixed by Proteins.** See Gelatin-Dynamite
with Improved Plasticity

**Gelatin-Dynamite Containing Oxazoline.**
Improvements in plasticity and extrudability
of gel dynamites are made by including 0.01–
0.1% of preferably, either 2-heptadecenyl-4-
methyl-4-hydroxymethyl-2-oxazoline or 2-
heptadecenyl-4-methyl-4-(hydroxydiethoxy-
methyl)-2-oxazoline
Re: Atlas Powder Co, BritP 725438 (1955) &
CA 49, 14325 (1955); USP 2727814 (1955) &
CA 50, 4510 (1956)

**Gelatine-Dynamite Containing Proteins.** See
Gelatin-Dynamite with Improved Plasticity

**Gelatin-Dynamite Containing S-Hollow Pellet.**
Improved high water pressure performance of
a gel dynamite is achieved by incorporating
hollow pellets of sulfur coated with clay or wax
Re: W.L. Reinhardt, USP 2674526 (1954) &
CA 48, 7904 (1954)

**Gelatin-Dynamite Containing Surface Active
Agents.** Triethanolamine olate 0.1 is added
to NG 21 and NC 0.5 at 120°F; then a blend of
AN 14.1, Na nitrate 49.1, carboneous combustible material 9.0, sulfur 6 & chalk
0.3 parts is added
Re: R.C. Glogau, USP 2676877 (1954) &
CA 48, 13222 (1954)

**Gelatin-Dynamites, Straight and Extra.** Acddg
to one source, the following straight formulation:
NG 50, NC 1.5, Na nitrate 38.0, carboneous matter 9.5 & chalk 1.0% is suitable for tough
blasting. The formulation called extra: NG
28.5, NC 0.5, AN 30.0, Na nitrate 30.0, car-
boneous matter 10.0 & chalk 1.0% is suitable for easy blasting
Re: Source, misplaced

**Gelatin-Dynamite Containing Triethanolamine
Salt.** Into a 70/30 blend of NG/NGc 20, DNT
2 & NC 0.3 stir for 5 min triethanolamine
oleate 0.025 and a mixture of C_{10-18} monohydrile alcohols 0.025; then add AN 14, Na
nitrate 49, carboneous material 7.9, sulfur
6.5 & chalk 0.3 parts
Re: R.G. Glogau, USP 2676878 (1954) &
CA 48, 13223 (1954)

**Gelatin-Dynamite Containing Water.** Mix AN
77.1, K nitrate 5, carboneous fuel 7.8, NC
gel 22.8, guar gel 8 (8–12 parts water per
part guar). The result is a gel dynamite in-
sensitive to a No 2 cap in the open, compared
to the No 1 cap sensitivity of a gel of the same
sp gr and deton velocity but prep'd with NC gel
30 and no guar gel
Ref: T. Sakurai, USP 2847291 (1958) & CA
52, 19144(1958)

Gelatine-Explosives. They include compns
listed here as Gelatins, Gelatine Aldorfit,
Gelatine Astralit, Gelatin Dynamites, etc

Gelatine-Gamsit, also known as Gamsit.
One of the Swiss, nonpermissible Gelatine
Dynamites, manuf'd by the Société Suisse des
Explosifs, Gamsen bei Brigg. The formulation
of NG with NGc 22, Collod Cotton 1.5,
DNT with TNT 13 & AN 63.5%, given by
Stettbacher (Ref 2) on p 86, under "Schweizerische
Nitrogelatinedynamiten" seems to
be identical with that of Gelatine Aldorfit
manuf'd by the Schweizerische Sprengstoff-
Fabrik AG, Dottikon and with Gelatine-Telsit,
manuf'd by the Schweiz Sprengstoffe AG at
Isleiten

Accdg to Naoûm (Ref 1) compn of Gamsit
is the same as for Gelatine-Telsit (qv)
Refs: Naoûm, NG (1928), p 363 2) Stett-
bacher (1948), p 86

Gelatine-Leonit (Ger). One of the permissible,
low-freezing Gelatine-Dynamits contg Dinitor-
glycerin, manuf'd before WWII by Rummenohl
Fabrik of the Westdeutsche Sprengstoffwerke
of Dortmund. Other Dynamites of the same
type were Gelatine-Dahmenit and Gelatine-
Trenonit
Refs: 1) Naoûm, NG (1928), p 418 2) PATR
2510(1958), p Ger 67-L

Gelatine-Penthritins and Penthritins. The
late Dr Alfred Stettbacher of Zürich, Switzerland
invented in 1928 plastic, nonexudable,
expl blends of PETN with NG to which later
other ingredients were added. One of the
first compns consisted of PETN 80 & NG
20% and was found to be suitable for use as
a base chge in detonators with 0.04g LA as
a primary chge. Another compn was PETN
85 & NG 15% (Ref 1). This expl was tested
in 1933 by A. Izzo in Italy and found to be
stable after storge for 28 days (quoted from
Ref 4, p 223)

If the amt of PETN in formulation is
below 60%, it is necessary to incorporate up
to 6–7% CC (Collodion Cotton) in order to
improve the plasticity in resulting blend.
Such Dynamits became known as Gelatine-
Penthritins. If less brisant expls are desired,
some AN (Ammonium Nitrate), up to 50%, may
be incorporated, and such expls are known as
Ammon-Penthritins. Compositions and
some properties of such expls are given in
Vol 1, p A382-R, Table. For low-freezing
Penthritins, NG is mixed with NGc (Nitro-
glycol). Two formulations contg NGc are
listed among Ammon-Penthritins

Penthritins and Gelatine-Penthritins were
prep'd before WWII for research purposes by
the Société Suisse des Explosifs, Gamsen bei
Brigg and proved to be outstanding expls.
Later they proved to be very effective for
underwater explns. Two Penthritins, 1 & 2
of Table 17 were, accdg to Stettbacher (Ref
6), loaded in 1929–1930 in 2cm shells and
tested at Oerlikon Fabrik at muzzle velocity
\(v_o\) 840m/sec. No premature occurred. The
addition of about 15% Al powder increases
the efficiencies of Penthritins, while high
amounts seem to decrease it. For example,
addition of 30% Al to formulation 1 of Gelatine-
Penthritins decreased detonation velocity
from 8000m/sec to 7200

The Gelatine-Penthritins 1, 2 & 3 were
listed in Table 17, Vol 3 of Encycl, p
C443-R, but their properties were not given.
In the same place compn 4 was listed under
the name Gelatine-Penthritine-Perchlorite,
but its properties were not given

Six Penthritins and four Gelatine-
Penthritins formulations are given in Table
G17 including some properties
## Table G17
Penthritins and Gelatine-Penthritins of Alfred Stettbacher

<table>
<thead>
<tr>
<th>Composition &amp; Properties</th>
<th>Penthritins</th>
<th>Gelatine Penthritins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PETN</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>NG</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>NGc</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CC</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NH₄ClO₄</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Al (added)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density (loading)</td>
<td>1.49</td>
<td>-</td>
</tr>
<tr>
<td>Density (max)</td>
<td>1.72</td>
<td>-</td>
</tr>
<tr>
<td>Detonation Velocity, m/sec</td>
<td>8600</td>
<td>-</td>
</tr>
<tr>
<td>Trauzl Test, cc</td>
<td>530</td>
<td>-</td>
</tr>
<tr>
<td>Pb Block Compression, mm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Impact Test, 2kg Wt, cm</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>Heat of Expln</td>
<td>1450</td>
<td>1438</td>
</tr>
<tr>
<td>(H₂O vapor), kcal/kg</td>
<td>762</td>
<td>766</td>
</tr>
<tr>
<td>Volume of Gases</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>at NTP in liters/kg</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Temperature of Expln, °C</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Notes:**

1) A. Stettbacher, SS 23, 345-48
2) Ibid, AngewChem 43, 844-47
3) A. Stettbacher, Nitrozellulose 4, 222-27 (1933)
4) Ibid 5, 6-12 (1934)
5) A. Stettbacher, "Spreng- und Schiessstoffe", Raschier, Zurich (1948), 83-5 & 104
6) Dr A. Stettbacher, Private Communication, Zurich, Dec 14, 1953

---

### Table G18

<table>
<thead>
<tr>
<th>Components and Some Properties</th>
<th>Gelatine-Proserpit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No 1</td>
</tr>
<tr>
<td>DNCIH</td>
<td>20.0</td>
</tr>
<tr>
<td>NG</td>
<td>5.0</td>
</tr>
<tr>
<td>Colloidal Cotton</td>
<td>0.5</td>
</tr>
<tr>
<td>DNT</td>
<td>5.0</td>
</tr>
<tr>
<td>Cereal meal</td>
<td>2.5</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>36.0</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>4.0</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>21.0</td>
</tr>
<tr>
<td>K oxalate</td>
<td>6.0</td>
</tr>
<tr>
<td>OB to CO₂</td>
<td>0.4%</td>
</tr>
<tr>
<td>Trauzl Test, cc</td>
<td>225</td>
</tr>
</tbody>
</table>

**Note:**

Compare with Gelatine Werter-Astralit

**Notes:**

1) Naoum, NG (1928), 418
2) PATR 2510 (1958), pp Ger 67 & Ger 68

---

**Gelatine-Proserpit.** (Ger). A type of low-freezing, gelatinous Dynamite based on (DNCIH) Dinitrochlorohydrin. Table G18 lists two formulations:
Gelatine-Romperit (Ger). Accdg to F. Weichheit, "Sprengtechnik", C. Marhold, Halle-Saale (1953), p 37, its compn is the same as that for Gelatine-Donarit.

Gelatine-Telsit (Swiss). An expl manufd by Schweizerische Sprengstoffe AG Cheddite & Dynamit at Isleten for blasting in construction of tunnels thru the Alps. Its compn was, accdg to Naoum (Ref 1), NG 22.0, NC 1.5, DNT 21.0 & AN 55.5% and properties: OB to CO₂ ≈12.6, density 1.46, Trauzl test value 380cc, lead block compression 14.6mm and deton velocity 6700m/sec. Could be initiated with a No 6 Blasting Cap.

The same compn is given by Stettbacher (Ref 2) for Telsit with the same props as above, except density is given as 1.55. The same author gives in his later book (Ref 3) for Gelatine-Telsit, Gelatine-Gamsit and Gelatine-Aldorf it the following compns: NG (with or w/o NGc) 22.0, Collodion Cotton 1.5, DNT with TNT (called flüssiges Tri) 13.0 & AN 63.5%. Its props are given under Gelatine-Aldorf.

Refs: 1) Naoum, NG (1928), p 363
2) Stettbacher (1933), p 242 3) Stettbacher (1948), p 86

Gelatine-Treonouis (Ger). Gelatinous, low-freezing mining exps manufd before WWII by the Castropfer Sicherheitssprengstoffe at Hagen, Westfalia.

Two of the formulations are shown in Table G19.

<table>
<thead>
<tr>
<th>Ingredients and Some Properties</th>
<th>Gelatine-Treonouis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Gelatinized</td>
<td>47.5</td>
</tr>
<tr>
<td>Di-Trinitroglycerin mixture</td>
<td></td>
</tr>
<tr>
<td>DNT</td>
<td>5.0</td>
</tr>
<tr>
<td>Woodmeal</td>
<td>5.0</td>
</tr>
<tr>
<td>Amm nitrate</td>
<td>22.5</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>20.0</td>
</tr>
<tr>
<td>Trauzl Test, cc</td>
<td>400</td>
</tr>
</tbody>
</table>

Refs: 1) Naoum, NG(1928), 368 2) PATR 2510(1958), p Ger 68

Gelatines, Vergé (Swiss & Ger). Accdg to Naoum (Ref 2), Vergé received in 1913 Swiss parents for the four exps, listed here in Table G20.

<table>
<thead>
<tr>
<th>Composition &amp; Properties</th>
<th>Gelatine 62%</th>
<th>Gelatine 56.5%</th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitroglycerin</td>
<td>40.0</td>
<td>37.0</td>
<td>38</td>
<td>41</td>
</tr>
<tr>
<td>Liquid Nitrocompounds</td>
<td>17.0</td>
<td>15.0</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Guncotton</td>
<td>5.0</td>
<td>4.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Collodion Cotton</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>NH₄ClO₄</td>
<td>38.0</td>
<td>25.2</td>
<td>26</td>
<td>-</td>
</tr>
<tr>
<td>KClO₄</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>NaN₃</td>
<td>-</td>
<td>18.3</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>OB to CO₂</td>
<td>-5.4%</td>
<td>+1.1%</td>
<td>+1.0%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Trauzl Test</td>
<td>-</td>
<td>-</td>
<td>450cc</td>
<td>405cc</td>
</tr>
<tr>
<td>Pb Block Compression</td>
<td>-</td>
<td>-</td>
<td>20.6mm</td>
<td>18.21mm</td>
</tr>
<tr>
<td>Sensitiveness</td>
<td>-</td>
<td>-</td>
<td>Cap No 1</td>
<td>Cap No 1</td>
</tr>
<tr>
<td>Detonation Velocity, m/sec</td>
<td>-</td>
<td>-</td>
<td>6600</td>
<td>7300</td>
</tr>
<tr>
<td>Density</td>
<td>-</td>
<td>-</td>
<td>1.52</td>
<td>1.57</td>
</tr>
</tbody>
</table>
Note: Liquid nitrocompounds consisted of TNT 20, dissolved in liq m-DNT 80
Refs: 1) A.E. Vergé, SS 10, 104 & 158(1915) 2) Naoum, NG(1928), pp 364 & 365
3) Vol 5 of Encycl, p D1591, Table 1, under
DYNAMITE

Gelatin-Wetter-Astrolid (Ger). Compositions of two mining expls based on DNCIH (Di-
nitrochlorohydrin) are, accdg to Naoum (Ref 1), identical with Gelaine-Prosperit described here
A different compn, however, is given in Thorpe's (Ref 2): CNClH 16.0, NG 4.0,
Colloid cotton 0.5, MNT 1.0, DNT 4.0, AN 40.0, flour or potato meal 8.0, Na nitrate
7.5, charcoal 0.5, castor oil 2.0, Amm oxalate 2.5 & NaCl 14.0
Refs: 1) Naoum, NG(1928), p 418
2) Thorpe Dict, Vol 4(1940), p 554

Gelatin-Wetter-Nobelit (Ger). A permissible, gelatinous expl: NG (gelatinized) 30.0, AN
26.5, woodmeal 0.5, NaCl 40 & 3% of Ca nitrate in 50% aqueous soln
Refs: 1) Stettbacher (1948), pp 91–2
2) PATR2510(1958), p Ger 68

Gelatinization (Gelation or Jelling). It is conversion of a substance into a gel, such as by treating NC with NG or other solvents, such as acetone or mixture of ether-ethanol. Gelatinization of NG with NC is described under GELATIN in this Vol
Gelatinization of NG with NC in prep of smokeless propellants is described in Vol 3, pp C398-L to C403-L, under "Colloidng Agents and Colloidal Propellants"

Gelatinization Accelerants. In gelatinizing NC with a liquid expl, such as NG, the addition of 0.5–2% of a derivative of an aliphatic alc congl at least 2 hydroxyl groups, such as ethyleneglycol monoethyl ether, facilitates the process. Such substances
as EGMeE may be called "gelatinization accelerants"
Refl: H.H. Fassnacht, USP 1966090(1934)
& CA 28, 5672(1954)

Gelatinization Coefficient. See Coefficient de gelatinisation or Pouvoir gelatinisant (Fr) in Vol 3 of Encycl, p C389-L & R

Gelatinization or Jelling Coefficient of Soler(G). Under the term coeficiente de gelatinizacion, Soler & Vian (Ref 1) and Soler (Refs 2 & 3), designated G as weight in grams of NC of nitrogen content 11.80% or of 13.0% which became completely gelatinized after being kept in contact for 2 hours with 1 g of gelatinizer to be tested. It was assumed that 2 hours of contact gives sufficient time for gelatinization if there is any
In testing gelatinization of 13% N NC, three substances were examined: diphenylurethane, urethane and Et Centralite. In general, gelatinization increased with the temperature and at lower temps G's were different with each gelatinizer. It became, however, equal for all 3 substances at 174°. The work was extended later to MNPhenol, o-MNT; 2,4-DNT; tritolylphosphate and Et oxalate
An equation was derived for calculating G, in advance for various temps
Refs: 1) A. Soler & A. Vian, Ion (Madrid) 2, 743–52 & 833(1942) 2) A. Soler, Anales de la Universidad de Murcia, 1943, p 25
3) A. Soler, Anales de Fisica y Quimica (Madrid) 40, 266–80(1944)

Gelatinization Coefficient of Nitrocelluloses and Coefficient de plasticité. In the paper entitled "Plasticités des pâtes de Poudre B", the term "coefficient de plasticité" is defined and a simple apparatus for its determination is described
Refl: Anon, MP 19, 146–53(1922)
Gelatinization Rate for NC. The pulped & dried NC of various N contents was shaken and stirred with a mixture of 80/20 NG/NGc. Using a standard electrophotometer the light absorption was read at 60-second intervals. It was concluded that the rate varied with a number of factors, including N content, viscosity, the state of pulping of fibers, etc Ref: D. Fensom, Canad J Res 26B, 59–69 (1948) & CA 42, 4347 (1948)


Gelatinized Dinitrotoluene Explosives.
J. Rudloff and W. Allendorf patented in 1906 in Germany expls which contained DNT previously gelatinized by mixing with 0.6% Collodion Cotton: eg, Gelatinized DNT 18, TNT 14, KClO₃ 60–68, & Pb(NO₃)₂ 0 to 8%. These expls were more powerful than straight TNT because they contained sufficient oxygen for complete combustion Ref: Colver (1918), 678–79

Gelatinized or Gelatinin Dynamites.
Their definition is given here under GELATIN, and various expls are described under the titles of Gelatine Astralt, Gelatin Carbonic, Gelatin Dynamite, Gelatin Dynamite etc

See also under DYNAMITE in Vol 5, pp D1599 to D1602, Tables IV, V, VI, VII & VIII, and under GERMAN DYNAMITS AND THEIR SUBSTITUTES

Gelatinized or Gelatinin Explosives, French.
See under French Gelatinized Explosives, which include Gommes, Gelatinée 1B, Gélignites, Dynamite gelatinée, etc, p F195-L

Gelatinized or Gelatinin Explosives, German.
They are not segregated but described as individual expls, such as Gelatine Astralt, Gelatine Dahmenite, etc. A general description of German Dynamits (which includes Gelatine Dynamits) is given here under GERMAN DYNAMITS AND THEIR SUBSTITUTES and in Vol 5, p D1599 to D1602, under DYNAMITE
Gelatinized Trinitrotoluene Explosives. Plastic, low-freezing expls, introduced in 1911 by the "Société Universelle d'Explosifs" of Paris, were prep'd by mixing thoroughly at 40–50°C, 21–24 parts of liquid TNT with 1 or 2 parts of Collodion Cotton and gradually adding 78–75 parts of K Chlorate.

S. Nauckhoff patented the following mixture in 1911: Gelatinized TNT (consisting of 96% of liq TNT and 4% of mixt of Collodion Cotton 31, NH₄ClO₄ 43, NH₄NO₃ 26).

Ref: Colver (1918), 247

Diphenyl carbamyl allylamine,
(C₆H₅)₂N.CO.NH.CH₂.CH:CH₂, crysts (from alc), mp 117.5°C

Diphenyl carbamyl alkyllamine,
(C₆H₅)₂N.CO.NH.CH₂.CH:CH₂, crysts (from alc), mp 184°C

Ref: R. Lévy, MP 32, 309–12(1950)

Gelatinizing Agents. Same as Colloiding Agents described in Vol 3, pp C398-L to C403-L

Gelatinizers and Stabilizers for Smokeless Propellants. Giua & Guastalla (Ref) listed the following cmpds proposed by them: ailine, Centralite, DPhA (Diphenylamine), phthalide, α-naphthylurethane, ethyl oxanilate (C₆H₅NH.COOC₂H₅) and potassium oxanilate (C₆H₅NH.COOK).

Ref: M. Giua & G. Guastalla, Chimie & Ind (Paris) 29, 268–77 (1933) & CA 27, 2580 (1933)

Gelatinizers and Stabilizers for Smokeless Propellants. Lévy (Ref) described the prepn. of the following substances which he called "nouveaux stabilisants et gelatinisants":

Diphenyl carbamyl piperidine
(C₆H₅)₂N.CO.N(CH₂)₃, crysts (from alc), mp 123.5°C

Diphenyl carbamyl morpholine,
(C₆H₅)₂N.CO.N(CH₂)₂O

Crysts (from alc), mp 108.5°C

α-Naphthyl diphenyleurea, (C₆H₅)₂N.CO.NH.C₁₀H₇

Crysts (from alc), mp 185.5°C

β-Naphthyl diphenyleurea, same formula as above; crysts (from alc), mp 182°C

Diphenyl carbamyl diethanolamine,
(C₆H₅)₂N.CO.N(CH₂CH₂OH)₂, crysts (from alc), mp 124.5°C

Diphenyl carbamyl monoethanolamine,
(C₆H₅)₂N.CO.NH.CH₂.CH₂OH, crysts (from

Gelatinizing (or Plasticizing) Power of Substances in Explosives or Propellants. It is the ability of a substance, such as NC, PETN, Centmlites, etc to bond a liquid expl (such as NG or NGc) or a nonexp'l solvent (such as acetone or ether/alc) to a homogeneous or nearly homogeneous gelatinous or semigelatinous mass.

For testing gelatinizing power of CC (Collodion Cotton) a special test was designed by Escales. The test as later modified and described by Naoûm (Ref) was conducted as follows:

A sample of 2.5g of finely screened CC was placed in a small porcelain casserole, stirred (using a hardwood, plastic or horn spatula) with 97.5g of cold NG. The casserole was then placed on a water bath, heated to 65°C and the mixture kneaded for 20 minutes, while warm, with the same spatula. After this, the mass was cooled to RT without stirring and examined by cutting with a spatula. If the mass were cut in coherent lumps, which easily separated from the porcelain casserole, the gelatinizing power was called 1. If the mass were not very coherent and stuck slightly to the porcelain, its power was 2, and so on to the grade mark 5, depending on coherence and stickiness. CC which gave a very sticky or oily, non-cohesive gelatin was rejected because it would produce an easily-exudable Dynamite.

Although this method was crude, it gave, with a little practice, fairly reliable results.

Ref: Naoûm, NG (1928), 295
Gelatinous Dynamites with Explosive Base.
See Vol 5 of Encycl, pp D1 599 to D1602, under DYNAMITE.

Gelatinous Nitrate Containing Polyisobutylene-Gelled Naphthene Base. Increased plasticity of dynamite-type expls is achieved by adding 1–10% of a gel based upon naphthene oil 95 and polyisobutylene 5 parts. Lubricating oil, heat-exchange oil or petroleum may be substituted for the naphthene. Ref: J.M. Downard, USP 2537039 (1951) & CA 45, 2670 (1951).

Gelatinous Permissible Explosive. One of the French compns was given by Naoûm. (Ref: Dinitroglycerin 35.0, NC 0.7, AN 38.4, TNT 2.5, cellulose 2.0, Amm chloride 9.4 & Na oxalate 12.0%.) Ref: Naoûm, NG (1928), 420.

Gelation or Jelling. Same as Gelatinization.

Gelatit I. A German permissible expl: NG (gelatinized by Collodion Cotton) 30.0, AN 35.0 to 37.0, woodmeal 0.5–1.5, DNT (or DNT with TNT) 0 to 2.0, KCl or NaCl 32.0 & coloring matter 0 to 5%. Refs: 1) Pepin Lechalleur (1935), 414–15 2) Beyling & Drekopf (1936), 100 3) PATR 2510 (1958), p Ger 68-L.

Gelbin. One of the names for Calcium Chromate listed on p C279 of Vol 3 of Encycl.


Gelbpulver (Yellow Powder). A Ger expl of WWII: TNT 54, NGc 18, NC (of 12% N) 27 and stabilizer (Acardite or Centralite) 1% colored yellow. Prepns and props are in Ref. Ref: Anon, German Report Rak 3, II, March 1943, translated at PicArsn Library by Dr. G. Loeht.

"Gelex". Trademark of DuPont & Co, registered in US Patent Office (Ref 3) for Semigelatin Dynamites (Nos 1 to 5 incl) having plasticity and water-resistance ratings between Ammonium Dynamite and Special Gelatin. Have a very good fume rating. Used in mining metallic ores, gypsum, limestone, in quarrying hard rock, and in construction work (Refs 1 & 2). Compositions are not given, but their bulk strengths, densities and detonation velocities are listed in Ref 3. Refs: 1) Cook (1958), 12 2) CondChem-Dict (1961), 530-L 3) Blasters' Hdb (1966), p 39, Table 4-3 and pp 40-1 & 510 4) PATR 2700, Vol 5 (1972), p D1604-R, under DYNAMITE, Class VI.

Gelgas or Gelled Gasoline. See under Flame Throwers-Liquids and Gels in Vol 6, pp F56ff.

GELIGNITE (Gelignit, in Ger; Gélignite in Fr; Gelignite in Ital, Gelignita in Span; Ghelignit in Russ).

Accdg to Daniel (Ref 1), Gelignites are certain varieties of Gelatin-Dynamites, which originated in England at the end of the 19th century. He lists eight varieties authorized between 1897 & 1898 for use in coal mines contg firedamp (grisou) and dust (poussière). The names of these Gelignites were British, Kynox, Nahusen, National, Nobel, Rhenish, Stowmarket and Sun. Their compns range is NG 54 to 64, NC 2 to 6, saltpeter 24 to 34 & wood flour 5 to 10.

Accdg to Marshall (Ref 2, p 369), Gelignite was introduced to replace Blasting Gelatine which was too violent for certain kinds of work, too local in its action and too expensive on account of large proportion of NG. Gelignites used during WWI consisted...
of 56 to 63% NG thickened with CC (Cello-
dion Cotton) to a thin jelly and mixed with
K nitrate and WM (woodmeal), with the addi-
tion, sometimes, of Ca carbonate and mineral
jelly. A typical compn for Brit Gelignite as
given on p 370 of Ref 2 was: NG 60.5, CC
4.5, K nitrate 27.0, WM 7.0, Ca carbonate
0.2 & moisture 0.2%. For comparison, the
compn of Brit Gelatine Dynamite used at
that time was: NG 74.5, CC 5.5, K nitrate
15.5, WM 4.0, Ca carbonate 0.2 & moisture
0.3% and of Blasting Gelatine: NG 91.5,
CC 8.0, Ca carbonate 0.2 & moisture 0.3%

As was mentioned here under GELATIN,
the Gelignite contd NG 60, CC 4, K nitrate
28 & WM 8% is one of the Brit "standard"
gelatinized explos (Ref 3, p 104) and its
ballistic pendulum swing is 3.27 inches for
4 oz sample (Ref 3, p 184). Its deton ve-
locity is 6600m/sec vs 7000m/sec for the
above 74.5% Gelatine Dynamite (Ref 3, p
191). Another Brit Gelignite contd NG 63.5,
CC 1.5, Na nitrate 27.0 & WM 5.0%, and its
deton vel was 6210m/sec at d 1.67 (Ref 3, p 118)

Accdg to definition given by Taylor & Gay
(Ref 7), Gelignites are industrial expls contg
less NG–NC jelly and more woodmeal and
O–contg salts than Gelatine-Dynamites. They
are plastic in nature and should not be con-
fused with "semi-gelatinized" which are betw
powdery and plastic expls. The Dynamites
which are powdery are now called in GBritain
"Powders" (These seem to correspond with
Amer Straight Dynamites)

McAdam & Westwater(Ref 8) list the fol-
lowing Brit Gelignites: 1) Gelignite 62%.
NG+NC 65, Na nitrate 28 and combustible
materials with stabilizer 7%; density 1.5,
deton velocity 2500m/sec and temp of expln
3730°C
2) Gelignite 42%. NG+NC 45, Na nitrate 44
and combustible material with stabilizer 11%;
density 1.55, deton vel 2500m/sec and temp
of expln 3290°C
3) Polar Ammon-Gelignite. NG+NC 30, AN
58 and combustibles with stabilizers 12%;
density 1.45, deton vel 2500m/sec and temp
of expln 2685°C and for comparison:
Polar Ammon-Gelatine-Dynamite. NG+NC
35, AN 60 and combustibles with stabilizer
5%; density 1.40, deton vel 2500m/sec and
temp of expln 3525°C

For comparison we are listing here the
German Gelignite II. NG 47.5, Celloid Cotton
2.5, K nitrate 37.5, woodmeal 3.5 & rye flour
9.0% (Refs 4, 5 & 9)

Gelignites, although originally industrial
expls, were used during WWII by the British
and American Armed Forces mostly for de-
molition charges, but also in some A/T
mines and in Stickey Grenades. They were
used under the names of Saxomite or Nobel’s
803(808, 223 or 853). A typical compn was
NG (gelatinized with 2–7% Celloid Cotton)
50, the rest being a mixt of Na nitrate &
woodmeal (Ref 6)

Accdg to Ref 10, commercial Gelignite
"60" was used in demolition charges weigh-
ing 4 or 1½ oz, wrapped in wax paper. Gel-
ignites "60" and "50" were used in Aus-
tralian Demolition Cartridges weighing 5½ oz

Gelignites also were used in Belgium,
France, Germany and Italy. In Spain it was
not listed as Gelignita (See Ref 6)

Refs: 1) Daniel (1902), 339–40 2) Mar-
shall 1(1917), 269–70 3) Barnett (1919),
104, 118, 184 & 191 4) Naoum, NG (1928),
330 5) Davis (1943), 345 6) All & EnExpls
(1946), 151–52 6) Vivas, Feigenspan &
Ladreda, Vol 2(1946), 398 (Comp listed as
Dinamita goma núm 2: NG 49.0, NC 2.5, Na
nitrate 35.5 & flour 13.0% of Fábrica de
Galdácano is similar to Brit & Ger Gelignites)
7) Taylor & Gay (1958), 24–5 8) McAdam
& Westwater (1958), 29–31 9) PATR 2510
(1958), p 68-R 10) Anon, "Explosives and
Demolitions", US Dept of Army Field Manual
FM 5–25 (1967), 10

Gelignite d’Ammoniacque. A Belgian permis-
sible expl contg NG 29.3, AN 70.0 & CC 0.7%.
It is identical with French Grisoutine-gomme

Ref: Daniel (1902), p 23
Gelignite, Ammon. See Brit nonpermitted expl listed as Ammon-Gelignite on p A368 of Vol 1 of Encycl, Table

Gelignite all'ammonio. Ital nonpermissible expl listed in Vol 3 of Encycl, p C440-R

Gélignite d'Arendonck. Belg mining expl: NG 56.20, Colloid Cotton 1.80, Na nitrate 31.29, woodflour 10.08 & Na carbonate 0.63% Ref: Gody (1907), 360

Gélignites (Belg). Mining expls: 1) NG 58, Colloid Cotton 2.5, woodpulp 8.0 & Na nitrate 31.0%; 2) NG 60.51, Colloid Cotton 4.88, woodpulp 7.18 & K nitrate 27.48% Ref: Gody (1907), p 375

Gélignites (Belg & Fr). Daniel (Ref) gives compns of Belgian and French Gelignites contg the following % NG: 57, 57.5, 57.86, 60 & 64. Other ingredients were NC, K or Na nitrate & woodmeal Ref: Daniel (1902), pp 328–29, Table

Gelignite (Ital). Nonpermissible expl listed in Vol 3, p C440-L (bottom)

Gel for Incendiary Bombs. Addition of 8–15% lanostem to petroleum hydrocarbons forms a solid gel suitable for use in incendiary bombs (See also Napalm) Ref: P. Vaterrodt, USP 2719782 (1955) & CA 50, 3764 (1956)

Gel-lacquer Application. Gel-lacquers are solns of polymer in relatively weak solvents, the compn of the soln being adjusted so that it is fluid at about 50°C. As the coated article is withdrawn from the bath, the air at RT cools the coating and immediately sets it to a nonflowing gel before sagging & running can take place. The lacquer subsequently goes thru the final drying stages with loss of solv in the usual time. If the article being dipped is cool enough or has sufficient heat capacity & good thermal stability, the layer of gel will form while the article is still immersed in the bath, and in this case an even thicker layer is applied. It is under these circumstances that dried layers of lacquer as thick as 0.015 inch can be applied

The solvents which have been employed are the cheaper paint & lacquer solvs. The gel-lacquer technique had been worked out for two classes of polymers, and in time may now be extended to most lacquer polymers Ref: Dr L. Gilman, "Plastics Developments", PA Technical Div Lecture, Picatinny Arsenal, delivered 31 Jan 1947, pp 8–9

Gelled Gasoline. See Gelas under Flame Throwers-Liquids and Gels in Vol 6, p F56ff


Gelled Liquid Nitroparaffins, such as Nitromethane, contg 3–75% NG, some amine and up to 3% of Cr acetylacetone, may be used as an expl or a propellant. The gels are liquid if small amts of NC are used, and solid if the amts are high Refs: H. Maisner, USP 2690964 (1954) & CA 49, 618 (1955)

Gelled Propellant Safety Investigation. Intermixing of gelled N₂O₄ & UDMH (unsymmetric dimethylhydrazine) results in a fire if large surface areas of gelled fuel & oxidizer come in contact. The fire is similar to that which occurs when two hypergolic propiants are
mixed in their liquid state. A small controllable fire will occur when small surface areas of the gel come in contact.

A large scale spill of liq propellant will result in splashing & spreading over a large area. A spill of the same amount of gel will remain in a much smaller area and result in increased safety to personnel in the area.


Gelling (or Jelling) Point. The setting point (concentration and temperature) at which semiliquids or pastes become solid.

Ref: Hackh's Dict (1944), 372-R

Gelling Normally Liquid Hydrocarbons.

Benzene, 50 parts may be gelled by adding potassium tridecylnaphthanate 3 parts; naphtha 50 parts will further stabilize the gel.

Possible uses are solid fuels, lubricants, military incendiaries & hydraulic fracturing fluids. Addition of w, 3%-5%, will liquefy the gel.


"Gelobel". A series of DuPont gelatinous and semigelatinous permissible dynamites. Of these "Gelobel" AA has deton vel 16500 ft/sec, when fired unconfined with Straight Dynamite primer. It has excellent water resistance and is intended for use in the most difficult types of rock work. The "Gelobel" C has deton vel 12100 ft/sec, and good water resistance. It is more economical than AA and best suited to soft rock and jobs that do not require heavy burden.

No compacts of these expls are given in Refs: 1) DuPont Blasters' Hdb (1966), pp 44 & 46 2) CondChemDict (1961), 530-L; (1971), not found

Gelose. Accdg to Hackh's (Ref 2), it is the same as galactan (qv), but accdg to Pérez Ara (Ref 3), it is the same as agar-agar.

Under the name of "gelose", or "agar-agar", it was used as a plasticity controlling component of some expls, such as Grenée (Poudre). It is called in Ref 3 Pôlvora Grenée. An older French expl cond NC 60, Ba nitrate 30, K nitrate 6, "gelose" (agar-agar) 3 & paraffin 1%. Naoûm (Ref 1) lists the comp of Wetter-Wasagit A, "gelose" 1%, the rest being NG (gelatinized) 28.0, AN 20.0, Ba nitrate 10.0, KCl 40.0 & talc 0.5%. It was manufd by the Westfälisch-Anhaltische Sprengstoff AG at Sythen and Reinsdorf Plants.


Gélosine. A substance contg about 98% water, obtred from some sea algae. It was recommended by Chalon & Guézinfor use as tamping in boreholes of gaseous coal mines. It was claimed that vapor resulting from evaporation of algae water during expln, diminished the temp of gases of expln, thus preventing the danger of firedamp expln.

Ref: Daniel (1902), 340

Geloxites. Brit safety explosives contg NG 54-64, K nitrate 13-22, Amm oxalate 12-15, woodmeal 4-7 & red ochre 1%.

Ref: Clift & Fedoroff, Vol 2, p G2

Gelsemine, C₂₉H₄₂N₂O₁₀, mw 436.22; prisms (from acet), mp 178°C; insol in w; sol in alc, ether, chl, and dilute acids. A poisonous alkaloid obtred from rhizome and root of Gelsemium sempervirens. Used in medicine as an analgesic and antispasmodic.

Gelsemine, Nitration. Nitration of gelsemine yields only an amorphous material. Nitration of dihydrogelsemine in mixed acid at -7 to +5° gives Dinitrogelsemine, analyzing for C_{20}H_{22}N_{6}O_{6}, mw 458.22, yel ndls (chlf or alc), mp 257-8°; sol in chlf, pyridine; sl sol in acet, methanol, alc, benz, eth & w. The dinitro cpd forms a nitrate salt, yel rhombic prisms, mp 219-21° dec
Ref: T.Q. Chou & T.T. Chu, JACS 63, 827 (1941) & CA 35, 2897 (1941) (Nitration)

Gemplé Explosive, patented in England in 1882, was also manufd in Switzerland under the name of Amidogène (See also Amidogène in Vol 1, p A171-R)
The Gemplé Explosive contained Amm Nitr 73, bran or starch 8, charcoal 8, sulfur 10 and Mg sulfate 1%. The ingredients were mixed in wet condition and grained and dried. The mixture was suitable as a gun propellant and for blasting operations. It was used for blasting works at the Iron Gate on the Danube. Because the powder was hygroscopic, it was necessary to load it into waterproof cartridges
Ref: 1) Candill, MP 5, 346 (1892)
2) Daniel (1902), 20 & 340

Generators, Chemical and Smoke Producing. (Apparatus for producing gas or vapor). In Chemical Warfare Service (See CHEMICAL AGENTS in Vol 2, pp C165-R to C171-R), it refers to a generator for producing poison gas, lacrimary gas or smoke. For example, the German Z5 Generator, originating in France, consisted of a rectangular sheet metal container in which a paper bag was filled with the following liquid mixture: DM (Adamsite) 43.2, Amm Perchlorate 28.5 and urea resin syrup 28.3% (Ref 1). On breaking the container a poisonous gas was emitted. Compn of DM is given in Vol 2, p C167-R
In a Brit classified Rept (Ref 2) are listed, but not described, generators producing chemical, lacrimary and smoke gases

Accdg to Bateman (Ref 1), all German smoke generators of WWII examined by him, consisted of a sheet metal container filled with one of the varieties of Berger mixtures. The containers were provided with one or several emission holes. In Berger mixtures hexachloroethane (abbrd as Hexa) was used as a source of chlorine which reacted with powdered Zn or Fe. All smoke comps were ignited by means of an igniter assembly. Some of the smoke generators were called Smoke Candles (Nebelkerze or Rauchkerze). For example, Nebelkerze 39B shown here

![Diagram of Nebelkerze 39B]

in Fig was described in Ref 1, pp 10-12, Ref 3, pp Ger 182-83 and earlier by F.G. Haverlack in PATR 1440 (1944). It was a sheet metal cylinder 91mm in diam and 140mm long filled with "Hexa" 59-60 & Zn dust 35-40 with Ba nitrate 1-2% added. Total wt was 4 lb, 2½ oz. For operating the NbK 39B the pull ring of the igniter, connected to a friction wire, was quickly withdrawn thru 0.035g of priming compn contg antimony sulfide 54, K chlorate 33 & MF 13%. The
resulting spark ignited 0.315g of upper mix: Pb₃O₄ (red lead) 75.4, silicon & fuel with binder 6.6% and a lower layer 1.82g of Pb chromate 50, K perchlorate 23.5, silicon 25.5 & binder 1.0%. After burning for 3 seconds, the smoke charge was ignited and gases generated on burning forced an exit thru the two holes in the steel top. A large vol of grey smoke was emitted for about 3 mins.

One of the generators, namely Parachute Recognition Smoke Generator was described in TM 9-1985-2 (1953), pp 89-92 and in Ref 3, pp Ger 183-84. Its Fig shown there is not reproduced here because it is too complicated. The device consisted of an Al cylinder, divided into two sections, one housing the canisters with smoke producing compn, while the other the parachute. The smoke compn consisted of a heat-stable blue dye 42 mixed with K chlorate 33 & lactose 25%. As priming compn BrPdr was used. The description of functioning is given on p Ger 184-L of Ref 3


Genetron 1132A. Designation of Difluoroethylene or Vinylidene Fluoride, described in Vol 6 undet FLUORINE DERIVATIVES, p F126ff

Gentisic Acid and Derivatives

Gentisic Acid or 2,5-Dihydroxybenzoic Acid, C₆H₄(OH)₂COOH; mw 154.12, colorless crystals mp 199-200°C; sol in w, alc & ether; insol in CS₂, chlF & benz. Can be prep'd from hydroquinone, KHCO₃ & water at 130°C. Used in medicine as Na gentisate


3-Nitrogentisic Acid, C₆H₄(NO₂)(OH)₂COOH; mw 199.12, N 7.03%; crystalline, mp 230°C (dec). Prepd from C₆H₄(OAc)₂COOCH₃ and sp gr 1.52 nitric acid at ambient temp


4-Nitrogentisic Acid, C₆H₄(NO₂)(OH)₂COOH; mw 199.12, N 7.03%; yel crysts (from w), mp 242°C; mp subl at 180°C; sol in alc & hot w; insol in most organics. Prepd from the parent & nitric acid in cold eth


Dinitrogentisic Acid, C₆H₂(NO₂)₂(OH)₂CO₂H; mw 244.12, N 11.48%; OB to CO₂ -52.5%. There is no mention of this compd in the open literature

Refs: 1) Beil, not found 2) CA, not found

Trinitrogentisic Acid, C₆(NO₂)₃(OH)₂CO₂H; mw 289.12, N 14.53%; OB to CO₂ -30.4%. There is no mention of this compd in the open literature

Refs: 1) Beil, not found 2) CA, not found

GEOM. An ItaI nonpermissible expl de- described in Vol 3 of Encycl, p C439-L (Two formulations are listed)

Geophone. An extremely sensitive electromagnetic device used as recording instrument in seismic prospecting. See in this Vol, under "Exploration for Natural Gas and Oil by Seismic Method", p E358-L to E359-L

Geophysical Prospecting. See under "Exploration for Natural Gas and Oil by Seismic Methods" in this Vol, p E358-L to E359-L
German Ammunition. Bibliography is listed in PATR 2510 (1958), pp Ger 6 to Ger 7.

German Bombs are described, with numerous illustrations in PATR 2510 (1958), pp Ger 14 to Ger 20.

German Cannons (Guns). See PATR 2510 (1958), pp Ger 238 to Ger 259, under WEAPONS.

German Carbins and Rifles. See PATR 2510 (1958), pp Ger 230 to Ger 237, under WEAPONS.

German Commercial (Industrial or Mining) Explosives (Gewerblichesprengstoffe) of WWII. See PATR 2510 (1958), pp Ger 29 to Ger 30, including Table 9; also under GELATIN EXPLOSIVES and under GERMAN DYNAMITS AND THEIR SUBSTITUTES below.

German Deep Bonding Process. See Vol 3 of Encycl, pp D37-L to D38-L.

GERMAN DYNAMITS AND THEIR SUBSTITUTES

Introduction

Accdg to Stettbacher (Ref 1, p 233), they may be subdivided into:
1) Gubrdynamit, which is an obsolete Dynamite with the inactive base Kieselguhr. It usually contained NG 75 & Kieselguhr 25%
2) Mischdynamite (Mixture Dynamites), which are nongelatinous (powdery) Dynamites with active base, such ad woodmeal and nitrates, with NG content 12–4%. They correspond to American “Straight Dynamites”. The Ammon-sprengstoffe (Ammonium Nitrate Explosives) belong to this group
3) Sprenggelatine corresponds to Amer “Blasting Gelatin”
4) Gelatine dynamite corresponds to Amer “Gelatin Dynamites” of which schwefrgefrierverbar (difficultly frozen) Sicherheitsdynamite (Safety Dynamites) contain as an admixt to NG either NGc, DNCH or aromatic nitrocompds, such as mixtures of DNT with TNT
5) Wettersichere Dynamite (gelatinous and nongelatinous) are those safe to use against firedamp and coal dust. They correspond to Amer “permissible” or British “permitted” Dynamites
6) Pentritins are low-freezing mixtures proposed by Dr Stettbacher in 1929. These mixtures consist of NG with 20% or more of PETN (Ref 2, pp 83–4 & 104). Another Dynamite developed by Dr S is Gelatine-pentritin. It consists of Gelatine-Dynamit (such as contg NG with NGc 62.5, Collodion Cotton 2.5, Na nitrate 27 & woodmeal (or rye flour) 8%, with or without prepared chalk (Schleimkreide) up to 0.5%), to which is added PETN, at least 15%. It is claimed that Gelatine Pentritin is not affected by “aging” as are other Gelatin-Dynamites (Ref 2, p 85). Ger Dynamites used for rock & ore blasting are known as Gesteinsdynamit.

German Dynamites used before and during WWII are listed in PATR 2510 (Ref 3) and also in this Encyclopedia. A complete list of A to D compns and description of E to Z compns are given under DYNAMITES AND THEIR SUBSTITUTES:

- Alkalsit I, Ammonal, Ammoncabüsit, Ammoncarbonit (Ammonkarbonit), Ammondynamit, Ammongelatine, Ammongelit, Ammonit, Ammon-Nobelit, Ammonpentrinit, Ammonsprenggelatine, Anagon, Argonit, Arth, Astralit, Barbarit, Bautzener-Sicherheitspulver, Bavart, Berclavit B, Bergmann, Bicarbonit (or Bicarbonit), Bichel, Bielefeld, Bohlit, Brank (von), Cahmeit, Calcinit,
- Carboazotin, Carbonit, Celtite (or Zeltit), Chemische Fabrik AG Dynamites, Chloratit, Chlorat-Rivalit, Chloratit, Chrome-Ammonit, Claessen, Cologne (Köln)-Rottweiler Safety Powder, Dahmen, Dahmenit, Detonit, Ditmar’s, Donar, Donarit, Donalin, Duxit, Dynamit N, Dynamit 1, Dynamit 2, Dynamit 3, Dynamit 4, Dynamit 5, Dynamite of Trauzl & Abel (also known as Guncotton Dynamite), Dynammon Sprengstoffe, Energit (or Nitroglycerin Powder), Ersatzdynamite, Fördit, Fuchs Powder, Fulmenit and Fulminatin
The following German explosives are listed here with prefix German:
Gelatin Dynamites (See Ger Gelatine-Astralit to Ger Gelatine-Wetter-Nobelit), Gelignit II, Gesilit, Gestein-Dynamite (See Ger Gesteins-Albit to Ger Gesteins-Westfalit), Glückauf, Glukodine, Gummidynamit, Gun cotton or Trauzl Dynamit, Guhrdynamit, Guhrhellhofit, Haloklastit, Hellhoffit or Hellhoffsprenstoff, Hexaklin, Hexonit, Hexoplast 75, Kessen-sprengstoffe, Kinetit, Kohlen-Dynamites (See Ger Kohlen-Albit to Ger Kohlen-Westfalit V), Kolax, Kolfit, Koll's Blasting Powder), Kronit V, Kubin Powder, Lansdorff, Leonit

German Electric Fuzes. See PATR 2510 (1958), pp Ger 40 & Ger 41 with two illustrations

German Fillers (Bursting Charges) for Projectiles. See German Military Explosives of WW II

German Flares. See PATR 2510 (1958), pp Ger 49 to Ger 51 with illustrations

German Fuzes. A comprehensive description with numerous illustrations is given in PATR 2510 (1958), pp Ger 54 to Ger 64

German Gelatine. See under GELATIN in this Vol

German Gelatine Dynamites are listed in this Volume under their individual names, such as Gelatine Astralit (Ger), Gelatine Carbonit (Ger) and under Gelatine-Dynamits (Ger). See also PATR 2510 (1958), pp Ger 66-L to Ger 68-L

German Gerlich Projectile. See German Tapered Bore Gun Projectile

German "C" Propellant ("C" Pulver), developed before WWII by General Uto Gallwitz and collaborators is described in PATR 2510 (1958), pp Ger 70-R to Ger 71-R and in Vol 5 of Encycl, p D1536-R

German Gronoton (Grenades, Projectiles, or Shells) are described with numerous illustrations in PATR 2510 (1958), pp Ger 71-R to Ger 81-L

German Gudol Propellant (Gudolpulver) is described in PATR 2510 (1958), p G81-L & R and in Vol 5, pp D1537-R to D1538-R

German Guidance Systems and Guidance Missiles are described with numerous illustrations in PATR 2510 (1958), pp Ger 81-R to Ger 85-L and in this Vol

German Guns and Cannons. See PATR 2510 (1958), pp Ger 238 to Ger 259 & Ger 263, under Weapons

German Gun Propellants of WW II. The brief info given below is from PATR 2510 (Ref), pp Ger 140 to Ger 147, which contains the description of results of analysis of captured German propiants, conducted at Picatinny Arsenal, Dover, New Jersey (mostly by P.R. Hosken, Jr & H. Jadowitz of the General Laboratory) and also from documentary materials gathered by various American and British missions sent to Germany directly after termination of the War. The work conducted at PicArsn was summarized by A.B. Schilling and others in PATR's listed on p Ger 140-R of Ref. The reports of Amer & British missions are listed on the same page

In Tables included in Ref are listed 26 Single-Base (NC) Propellants, 23 Double-Base (NC-NG) Propellants, 41 Double-Base (NC-DEGDN) Propellants, 11 Triple-Base
(NC-DEGDN-NGu) Propellants and Artillery Propellants described by H.H.M. Pike in CIONS Rept 31-68(1946). In Table 46 on p Ger 146 are listed ballistic properties and uses of several propellants. Abbreviations used in Tables: DEGDN means Diethylene-glycol Dinitrate and NGu is Nitroguanidine, called Picrite in G Britain. Many of the German proplants of WWII were original and not known in other countries. The most important of these propellants were "cool" propellants developed, beginning in 1934, under the direction of General Uto Gallwitz. These NC-DEGDN propellants known as "G" Pulvem (or "K" Pulvem) are briefly described in Vol 3 of Encycl, pp C511-R to C512-L and in Vol 5, p D1536-R. For uses in hot climates (such as in Africa), DEGDN was replaced by TEGDN (Triethylene glycol Dinitrate). Some of these propellants, known as DiglP and TriglP are listed in PATR 2510, p Ger 147-L.

The "cool" Triple-Base (NC-DEGDN-NG) Propellants, known as GuP (Gudolpulvem) are described in Vol 5, pp D1537-R to D1538-L, and also in PATR 2510, p 147-L.

Ref: B.T. Fedoroff et al, PATR 2510(1958), pp Ger 140 to Ger 147

German Handgrenades. See PATR 2510 (1958), p Ger 86 (Illustrated)

German HDP Supergun [Hochdruckpumpe, V-3 (Vergelenungswaffe 3), High Pressure Pump, "Busy Lizzie" or "Multipede"]). See PATR 2510(1958), p 90 (Illustrated)

German Hollow Charges (Hohlladungen) or Shaped Charges. See PATR 2510(1958), pp Ger 91-L to Ger 93-L (Illustrated)

German Igniters. See PATR 2510(1958), pp Ger 93-R to Ger 99-L (Illustrated)

Germanium, Gdolinium and Gold Salts were proposed as ingredients in smoke producing compns
Ref: J. DeMent, USP 2995526(1961)

German Land Mines (Landminen). See PATR 2510(1958), pp Ger 104-L to Ger 107-L (Illustrated)

German Long Range Guns. See Big Bertha, Paris Gun and Other German Big Guns of WWI and WWII in Vol 2 of Encycl, pp B113-R to B114-L. Also in PATR 2510(1958), pp Ger 258 & Ger 259, under Weapons

German Mann Salt (MAN-Salz). See PATR 2510(1958), pp Ger 108-L to Ger 109-R

German Markers. See PATR 2510(1958), pp Ger 110 & Ger 111 (Illustrated)

German Message Tube (Meldebuchse). See PATR 2510(1958), p Ger 112

German Mortar Trinitrate. See PATR 2510 (1958), p Ger 113-L

GERMAN MILITARY EXPLOSIVES OF WWII.
The expls used as bursting charges (fillers) for bombs, shells and grenades were known under the name Füllung or Füllpulver (abbrd as Fp), followed by some number, signifying mostly the year of adoption for Service. For example: Fp 02 signified TNT, which was adopted in 1902. Some of the fillers were not abbrd as Fp, but as Gf (Granatefüllung), as, for example Gf 88 signified Picric Acid. It was adopted in 1888 for filling shells.

In PATR 2510 (Ref 4) are listed 56 fillers, compiled from Refs 1 to 3
Refs: 1) Anon, "Recognition Handbook for German Ammunition", Supreme Headquarters
Allied Expeditionary Force (1945), pp 286-88
2) Anon, "Allied and Enemy Explosives", Aberdeen Proving Ground, Maryland (1946), pp 75, 79, 82, 86, 88, 97, 112, 113, 118, 120, 124, 129, 133, 134, 137, 139, 141, 142 & 147
4) B.T. Fedoroff et al, PATR 2510 (1958), pp Ger 146-R to Ger 148-R

German Military Explosives of WWI Used as Fillers in Anticoncrete and Armor-Piercing Shells. In order to make the explosives such as TNT safe for use in armor-piercing and anticoncrete shells, sections of TNT close to the nose were made less sensitive to shock by incorporating some wax & K chloride.

A good example of this type of filling was the one in 210mm Anticoncrete Shell (21cm GrBe). Its filler consisted of ten pressed pellets placed in cardboard container and held in position by a cement lining. The forward three sections 6, 7 & 8 were intended to provide protective layers, practically insensitive to shock, whereas the layers close to the base were nearly or just as sensitive as straight TNT. The following list gives the compositions and weights of charges shown in Fig G14

No 1  4 lb, 2 oz of TNT/Wax – 94/6
No 1a 8 oz of Straight TNT
No 2  4 lb, ¼ oz of TNT/Wax – 90/10
No 2a 1 lb, 5½ oz of Straight TNT
No 3  5 lb, 5½ oz of TNT/Wax – 90/10
No 4  5 lb, 4½ oz of TNT/Wax – 91/9
No 5  4 lb, 2 oz of TNT/Wax – 91/9
No 6  6 oz of TNT/Wax/KCl – 60.5/5.4/34.1
No 7  5 oz of TNT/Wax/KCl – 44.1/5.6/50.3
No 8  6 oz of KCl

Total weight of filler was 25 lb, 8¼ oz
Ref: 1) E. Englesburg, The Ordnance Sergeant, May 1944, p 320 2) PATR 2510 (1958), p Ger 48-R

German Mine Explosive of WWI. Due to the shortage of NG, some mine expls contd no such substance, as for example: DNB 32, DNN 12 & K perchlorate 56%
Ref: Davis (1943), 158

German Minenhund (Mine Dog), called by the Allies “Doodlebug” or “Goliath”. See PATR 2510 (1958), p Ger 113-L

German Muzzle Charging Device. See PATR 2510 (1958), p Ger 114

German Myrol and Its Explosives. See PATR 2510 (1958), pp Ger 114-R to Ger 116-L

German Natter Ba349A & Ba349B Guided Missiles. See PATR 2510 (1958), p Ger 116-R (Illustrated)
German Naval Explosives and Weapons of WWI and WWII were described by A. Stettbacher in Protar (Switzerland) 9, 33-45 (1943). The paper was entitled: "Ueber die Wirkung von Torpedos, Minen, und Tieflbomben unter Berucksichtigung der deutschen Marine-sprengstoffe vom letzten und heutigen Weltkrieg" (On the Work of Torpedoes, Mines, and Depth Charges in Regard to German Naval Explosives from the Last and Present World War).

During WWI Ger Whitehead torpedoes were loaded with Hexyl, which consisted of TNT 60 & HNDPhA (Hexanitrodiphenylamine) 40%. This was replaced during WWII with TNT 55.7, HNDPhA 27.9 & Al (grit 40-70 sieve) 16.4%. Another Ger compn of WWII contd (accdg to analysis of Dr Stettbacher) TNT 61.8, HNDPhA & Al 15.2%. The torpedoes were cigarer-like steel vessels 45-60cm diam and 5-10 meters long. They consisted of 3 compartments, of which the head (Kopf), also called warhead, contained the expl.

Straight PETN was found to be too sensitive for loading torpedoes. Ger sea mines (Sprengminen) were of the following types: contact mine (Kontakmine or Sosse- und Streumine), magnetic and acoustic mines. PETN, straight or in mixt with Al, was used as expl chge for mines.

Ger depth bombs (TieflBomben or Wasserbomben) were used against submarines. A typical bomb consisted of a metallic cylinder ca 50cm diam and 80cm long. It contd ca 350kg of expl, such as TNT, PA or aluminized TNT-HNDPhA.

German Napolit Propellants. See PATR 2510(1958), p Ger 117

German One-Man Torpedo. See German Torpedo, One Man

German Panzer (Armor or Armed Vehicle; Tank). See PATR 2510(1958), pp Ger 123-L to Ger 126-R

German Panzerfaust and Panzergranate. See PATR 2510(1958), pp Ger 126-R to Ger 127-L (Illustrated)

German Panzerschreck and Panzerwurfmine. See PATR 2510(1958), p Ger 127 (Illustrated)

German Permissible Explosives. See Vol 3 of Encycl, p C451-L

German Photoflash Bomb and Photoflash Composition. See PATR 2510(1958), pp Ger 130-R & Ger 131-L (Illustrated)

German Pistols of WWII. See PATR 2510 (1958), pp Ger 227 to Ger 229 (Illustrated)

German Pistol Grenades. See PATR 2510 (1958), pp Ger 132-R to Ger 134-L (Illustrated)

German Primary Compositions and Primers. See PATR 2510(1958), pp Ger 137-L to Ger 138-R (Illustrated)

German Propagandarakete (Leaflet Rocket). See pp Ger 138-R & Ger 139 (Illustrated)

German Propellants. See Gun Propellants on pp Ger 139-L to Ger 149 and for Rocket Propellants, pp Ger 166-R to Ger 168-L.
German Propellant Igniters. See PATR 2510 (1958), p Ger 151-L

German Proximity Fuze. See PATR 2510 (1958), p Ger 151-R (Illustrated)

German Püpchen or Wheeled Bazooka. See PATR 2510 (1958), p Ger 152-R (Illustrated)

German Pyrotechnic Antipathfinder Devices. See PATR 2510 (1958), pp Ger 152-R & Ger 153-R

German Pyrotechnics. See PATR 2510 (1958), pp Ger 153 to Ger 155-R

German R-4M Rocket. See PATR 2510 (1958), p Ger 155 (Illustrated)

German Recoilless Gun (Kanone ohne Rücklauf). See PATR 2510 (1958), p Ger 156-R

German Rheinbote (Unguided Missile). See PATR 2510 (1958), p 157-L (Illustrated)

German Rheintochter (Guided Missile). See PATR 2510 (1958), p Ger 157-R

German Rifle (Gewehr). See PATR 2510 (1958), pp Ger 229 to Ger 237, under Weapons

German Rifle Discharger. See Schiessbecher in PATR 2510 (1958), p Ger 172-L. (Illustrated)

German Rifled Projectile. See PATR 2510 (1958), p Ger 157-R

German Rifle Grenades. See PATR 2510 (1958), pp Ger 158-L to Ger 160-L

German Röchling Projectile. See PATR 2510 (1958), p Ger 160-R (Illustrated)

German Rocket (Rakete). See PATR 2510 (1958), pp Ger 160-R to Ger 163-R (Illustrated)

German Rocket-Assisted Shell. See PATR 2510 (1958), pp Ger 163-R to Ger 164-L (Illustrated)

German Rocket Launchers. See PATR 2510 (1958), pp Ger 164-L to Ger 165 (Illustrated)

German Rocket Propellants of WWII. Accdg to Urbanski (Ref 1), the Germans used solid double-base (NC-NG) proplts in their smaller rockets. The larger types, such as the V-2 (described in Ref 3, p Ger 213-R), used liquid propellants consisting of a fuel (such as hydrazine, alcohol, fuel oil, etc) and an oxygen carrier (such as hydrogen peroxide, nitric acid, Tranitenmethane, etc). Mixtures of easily oxidizable organic liquids with H_2O of 80–85% strength were the most widely used. Hydrogen peroxide was also used as the driving force without any fuel, because the heat liberated accdg to the reaction of decmp: H_2O_2 → H_2O + \frac{1}{2}O_2 + 23450 kcal, was sufficiently great. The liberated water vapor and oxygen served as driving force. Liquid proplts were also used for driving V-1, described in Ref 3, p Ger 213-L, with Fig on p Ger 214. Accdg to Tschinkel (Ref 2), some V-2 rockets were driven by a mix of liquid oxygen with alcohol contg some w, which was added in order to keep the flame temp as low as possible to avoid damage to the
combustion chamber. Incorporation of 25% w
in alc lowered the flame temp 7%, while
exhaust velocity of gases was lowered
only 3.5%. In 1944 preps were made to
replace liq oxygen with absol nitric acid

Table 53 of Ref 3, p Ger 167 lists six
formulations of solid rocket proplnts,
while Table 56 lists five formulations of
WASAG-AG, as reported in PB and OSRD
Repts listed on p Ger 168-L

Refs: 1) T. Urbasñski, Przemysl Chemiczny
27(4), 187(1948) 2) J.G. Tschinkel,
C&EN 32, 2584(1954) 3) PATR 2510
(1958), p Ger 167

German Rodded Bomb or Stick Grenade.
See PATR 2510(1958), p Ger 168 (Illustrated)

German R-Salt (R-Salz) and Its Explosives.
See PATR 2510(1958), p Ger 170

German Sabot Projectile. See PATR 2510
(1958), pp Ger 170 & Ger 171 (Illustrated)

German Sarin. See under German Trilons
and GB in Vol 2 of Encycl, p C167-R

German Sänger-Bredt Supersonic Missile
See PATR 2510(1958), p Ger 171-R

German Schnorkel or Snorkel. See PATR
2510(1958), pp Ger 172-R & Ger 173-L

German Sea Dog (Seehund). See PATR 2510
(1958), p Ger 174-L

German Self-Destroying Fuze, Tracer Bullet
and Tracer Shell. See PATR 2510(1958),
p Ger 176-L (Illustrated)

German Sebastopol Gun, cal 800mm, nick-
named Dora and Gustav Geschütz. See PATR
2510(1958), p Ger 176 and p Ger 259, under
Weapons

German Shrapnel Projectiles. See PATR
2510(1958), pp Ger 176-R to Ger 177-R

German Signal Device. See PATR 2510
(1958), pp Ger 177-R to Ger 179-L

German-Sinaxyd Priming Mixture. See PATR
2510(1958), p Ger 179-R

German Small Arms Ammunition. See PATR
2510(1958), pp Ger 180-L to Ger 181-L

German Smoke and Chemical Rocket. See
PATR 2510(1958), p Ger 181-R

German Smoke Bomb. See PATR 2510(1958),
pp Ger 182-L to Ger 183-R (Illustrated)

German Smoke Generator (Rauchentwickler).
See PATR 2510(1958), pp Ger 183-R to
Ger 184-L

German Smoke Hand Grenade (Blendkörper).
See PATR 2510(1958), pp Ger 184-L to
Ger 185-L (Illustrated)

German Smoke Projectile (Nebelgeschoss).
See PATR 2510(1958), pp Ger 185-L to
Ger 186-L (Illustrated)

German Soman. See under German Trilons in
this Vol and GD in Vol 2 of Encycl, p C168-L

German Sound Gun. See PATR 2510(1958),
pp Ger 186-R to Ger 187-R (Illustrated)
German Spigot Mortar Projectile. See PATR 2510 (1958), pp Ger 187-R to Ger 188-L (Illustrated)

German Spike Bomb. See Stachelbombe, abbrd Stabom, in PATR 2510 (1958), p Ger 190 (Illustrated)

German Spotting Projectile. See PATR 2510 (1958), pp Ger 188-L to Ger 189-L (Illustrated)

German Sprongbrandbombe. See PATR 2510 (1958), p Ger 189-L (Illustrated)

German 132° Stability Test. This test has been used in Germany for testing NC and powders. The test was formerly carried out at 135°, but the temperature was lowered to 132° and the observation was often confined to the visible brown fumes. Sometimes the test was run using a strip of litmus paper. The test is essentially the same as the German 135° Stability Test (qv)

Refs: 1) Reilly (1938), p 82 2) Kast-Metz (1944), p 233

German 135° Stability Test. This test originated in Germany about 70 years ago and was described by Sy (Ref 1, p 556). It was adopted by the US Ordnance Dept (Ref 2), but the temperatures of the test were 120° for double-base propellants and 134.5° for single-base propellants & for NC’s (Ref 3). Litmus paper was originally used in this test (Refs 1 & 2) but later this was changed to methyl violet paper and the test was called the “Methyl Violet Test”

Apparatus:
A cylindrical constant temperature bath containing glycerin-water mixture of density 1.21 for 120±0.5° and d 1.24 for 134.5±0.5°. The top of the bath is perforated and equipped with several metallic tubes about 285mm long and about 20mm ID, which extend into the liquid of the bath and serve to sheath the Pyrex test tubes. A calibrated thermometer is inserted in the glycerin-water mixture.

Heavy-walled Pyrex tubes 15mm ID, 18mm OD and 290mm long, are provided with ordinary cork stoppers; the side of each is notched to a depth of about 4mm.

Normal methyl violet test paper is prepd by soaking filter paper in a normal solution of rosinamine acetate-crystal violet and drying

Note: Standard methyl violet paper could be purchased from US Naval Powder Factory, Indian Head Maryland, changed to Naval Propellant Plant (NPP)

Procedure for NC and for Propellants

a) Weigh out two (or three) 2.5g portions of the sample (previously dried either for 4–5 hrs at 40±2° or for 1–1½ hrs at 50±2° or overnight at RT with further drying for ½ hr at 40±2°) and press them into the lower part of the Pyrex test tubes

b) Place a piece of standard normal methyl violet paper, 70mm long and 20mm wide, vertically in each tube, its lower edge being 25mm above the test material; stopper the tubes
c) Place each Pyrex tube into a metallic tube extending inside the bath maintained at 134.5±0.5° and observe the time

Note: No more than 6–7mm of either of the Pyrex tubes should project above the top of the bath

d) After 20 minutes of heating, examine each tube at five minute intervals by withdrawing one-half its length. Replace the tubes as quickly as possible to avoid cooling more than necessary
e) Record as a salmon pink (SP) value, the time in minutes required for the test paper completely change from violet to salmon pink.

When testing smokeless propellants, heating may be continued in order to determine the time at which visible “red fumes” (RF) are evolved. The test is usually also extended to a total of 5 hours heating in order to determine if the propint explodes.
in less than 5 hours (300 minutes)

On testing propgants, each sample should contain as many whole grains as possible but, if the grains are too large, they should be sectioned longitudinally

Requirements of this test vary with the propgants and are given in specifications. Generally, minimum "salmon pink" time is 30 minutes for NC, 45 mins for single-base propgants and 40 mins for double-base propgants.

Note: More detailed description as conducted at PicArsn is in Ref 3


**German Star Shell.** See PATR 2510(1958), pp Ger 190-R & Ger 191-L (Illustrated)

**German Steel and Iron Ammunition Items.**
See PATR 2510(1958), p Ger 191 (Illustrated)

**German Substitute Explosives of Wwi.** See Ersatzsprengstoffe in Vol 5 of Encycl, pp E121 & E122 (Table E15)

**German Supergun.** See German HDP Supergun (Hochdruckpumpe or V-3)

**German Tabun.** See under German Trilons and GA in Vol 2 of Encycl, p C167-R

**German Taijun Rocket.** See PATR 2510 (1958), p Ger 193-L

**German Tapered Bore Gun (Würgebohrung Geschütz).** See PATR 2510(1958), p Ger 193

**German Tapered Bore Projectile or Gerlich Projectile.** See PATR 2510(1958), pp Ger 193-R to Ger 195-R (Illustrated)

**German Tanks.** See German Panzer in PATR 2510(1958), p Ger 123 to Ger 127-L

**German Tarbun.** See under Trilons

**German Tellermine (Dish-like Land Mine).**
See PATR 2510(1958), p Ger 195

**German Tetan (TeNMe) or X-Stoff and Its Explosives.** See PATR 2510(1958), pp Ger 195 & Ger 196

**German "Thor" and "Karl" Mortars.** See PATR 2510(1958), p Ger 198-L

**German Tiger Tanks.** See PATR 2510(1958), p Ger 126-L, under Panzer

**German Torpedo, One Man.** See U-Boat, One Man in PATR 2510(1958), p Ger 211-L (Illustrated)

**German Torpedoes, Mines and Depth Bombs of Wwi and Wwii were described by A. Stettbacher in Protat (Switzerland) 9, 33-45 (1943)

**German Totalits.** See PATR 2510(1958), p Ger 199-R

**German Tracer Compositions and Tracers.**
See PATR 2510(1958), p Ger 199-R to Ger 202-L
German Tracer Projectiles. See PATR 2510 (1958), pp Ger 202-L to Ger 203-L (Illustrated)

German Tritons. Extremely toxic Chemical Warfare Agents developed before WWII but never employed. They included Sarin, Soman, Tabun and probably others. See PATR 2510 (1958), p Ger 204-L and GA and GB in Vol 2 of Encycl, p C167-R

German T-Stuff (T-Stoff). Concentrated Hydrogen Peroxide. See PATR 2510 (1958), p Ger 210

German U-Boat-21 (Unterseeboot-21). See PATR 2510 (1958), p Ger 211-R

German U-Boat, One Man. See German Torpedo, One Man

German U-Boat Walter. See PATR 2510 (1958), p Ger 211-R

German V-1 (Vergeltungswaffe Eins) (Re-venge Weapon One). German designation FZG-76; British name Buzz Bomb. See PATR 2510 (1958), p Ger 213 (Illustrated on p Ger 214)


German Vocabulary of Ordnance, etc. See PATR 2510 (1958), p Ger 265 to Ger 345

German Warplants, Arsenals, Research Centers and Proving Grounds. See PATR 2510 (1958), pp Ger 217 to Ger 225

German Weapons of WWI and WWII. See PATR 2510 (1958), pp Ger 227 to Ger 259 & Ger 263. Also R. Lusar, "Die Deutschen Waffen und Geheimwaffen des 2 Weltkrieges und Ihre Weiterentwicklung", Lehman Verlag, Munich (1958)

German (West) Weapons. These include: 1) Redesigned MG-42 machine gun firing 7.62mm NATO rounds; 2) Fully automatic Spanish Cetme rifle, also 7.62mm, firing at a cyclic rate of 650 rounds/min and 3) 20mm automatic cannon by Hispano Suiza, firing 800 rounds/min at a muzzle velocity of 1050m/sec
Ref: J. Weiler, Ordn 45, pp 351-354 (Nov-Dec, 1960)

German Wettersprengstoffe (Permissible Explosive). Definition is given in PATR 2510 (1958), p Ger 226 and list with compass in Table 64 on pp Ger 260 & Ger 261. Properties of some Wettersprengstoffe are in Table 65 on p Ger 261. Notes and Refs are on p Ger 262

German Wind Gun. See PATR 2510 (1958), p Ger 262 (Illustrated)

German Wind Tunnel. See PATR 2510 (1958), p Ger 262-R

German X-4 Guided Missile. See PATR 2510 (1958), p Ger 264-L

German X-Stuff. See German Tetan (TeNMe)

German Z-Salt (Z-Salz). See PATR 2510 (1958), p Ger 264-R

German Z-Stuff C and N (Z-Stoff C & N). See PATR 2510 (1958), p Ger 264-R
Gerresdorfer and Bols Powders, patented in 1892 in France, used Na chloride as a base, but in order to diminish its hygroscopicity it was coated with an alcoholic soln of a resin mixed with Mndioxide and with one or several other substances, such as K chloride, K chromate, sulfur, gum & charcoal
Refs: 1) Daniel (1902), 341  2) Giua, Trattato 6(1), (1959), p 395

Gesericke of Rotterdam, patented in 1895 a permissible expl consisting of AN 88.65, DNBz 7.50, MNaphthalene 0.50, Chloromaphthalene 2.35 & NC 1.00%
Ref: Daniel (1902), 341

Gesilits. German permissible WWI expls: No 1 - NG 30.75, DNT 5.25, Na nitrate 18.00, dextrin 39.00 & NaCl 7.00%; No 2 - NG 30.75, DNT 5.25, AN 22.00, dextrin 21.00 & NaCl 21.00%
4) Giua, Trattato 6(1), 1959, p 345

Gesteinsprengstoffe. German for Rock Blasting Explosives, which are listed below. They are suitable for blasting rocks, ores, potash concrete, etc, but unsuitable for use in coal mines cong in atmosphere firedamp and coal dust
Following is a partial list of Gesteinsprengstoffe:
Gesteins-Albit. See Vol 1, p A120-L
Gesteins-Dorfit. See Dorfit in Vol 5, p D1535-L
Gesteins-Koriniti T1: Na chloride 72.0, vegetable meal 1.0-2.0, TNT+DNR 20.0, paraffin 3.0-4.0 & NG 3.0-4.0% (Ref 1)
Gesteins-Koriniti T2: Na chloride 75.0, vegetable meal 1.0-2.0, TNT+DNT 20.0 & paraffin 3.0-4.0% (Ref 1)
Gesteins-Permonit: K perchlorate 30.0, AN 40.0, Na nitrate 7.0, TNT 15.0, flour 4.0, woodmeal 3.0 & jelly 1.0% (Ref 2)
Gesteins-Persalit 1: K perchlorate 35.0, AN 43.0, DNT 8.0, DNN 8.0, NG 2.0 & woodmeal 4.0% (Ref 2)
Gesteins-Persalit 2: K perchlorate 34.0, AN 48.0, DNT 10.0, carbon (powder) 2.0 & woodmeal 6.0% (Ref 2)
Gesteins-Westalit: AN 84.5, DNT 12.0 & Al 3.5% (Ref 2)
Refs: 1) Naoum, NG (1928), 428  2) PATR 2510(1958), p Ger 69

Gheksamon (Hexamons). Russ permissible expls based on 8-10% normally or finely dispersed RDX (Gheksogen in Russ) and powd AN (Ammiachnay Selitra, in Russ). Gheksamon Nos 1, 3, 5 & 6 are listed in Refs, but their exact comps are not given in CA's

Gheksoghen (Hexogen). Russ for RDX

Chinijonet used to manuf at Ougré, Belgium a permissible mining expl, Densite, described in Vol 3 of Encycl, p D64-R. He also manuf'd Tritorite, which consisted of AN 70, DNBz 18, K nitrate 11 & charcoal 1%
Ref: Daniel (1902), 341 & 775

Giant Coal Mine Powder and Giant Low Flame Powder (Amer). Accdg to Naoum (Ref) they were permissible Dynamites which contained hydrated salts and, for this reason, were called Hydrated Explosives. No comp is given in Naoum, but it seems that they were similar to Belg & French Dynamite-grisouites as, for example, NG 42, MgSO4·7H2O 46 & woodmeal (or guth) 12%
Ref: Naoum, NG (1928), 399

Giant Powder. Under the title Gelante (Poudre). Daniel (Ref 1) called this an older Amer name for Dynamite, manuf'd in Calif under the name Dynamite-Lignine, which contd Na nitrate.
Accdg to Naoum (Ref 4), the name Giant Pow-
der No 1 was applied to Dynamite No 1, which was Gahr Dynamite consisting of NG 75 & Kiesel-
guhr 25%

Accdg to Daniel (Ref 1), Giant Powder No 2 coned NG 40, Na and/or K nitrate 40, rosin 6, sulfur 6 & kieselguhr 8%. The same comp for Giant Powder is given by Ramsey & Weston (Ref 3). Gody (Ref 2), under the name Poudre
giant gives: NG 36, saltpeter 48, sulfur 8 &
rosin or charcoal 8%
Refs: 1) Daniel (1902), 324 2) Gody (1907),
p 363 3) Ramsey & Weston (1917), p 21
4) Naoûm, NG (1928), p 264

Giedyuim Powder, patented in 1868, consisted of K chloride, sulfur & silicon
Ref: Giua, Tratato 6(1)(1959), p 392

GI Explosive. Abbr for Government Issue Explosive

Gilging Metal. Accdg to Gardner (Ref 2) it is a reddish-yellow metal consisting of Cu 70, Sn 12.5 & brass 17.5%

Gilging metal is used for some military purposes. The requirements of US Armed Forces for gilding metal, called "95/5 Brass", are covered by Specification JAN-G-439 (Aug 1946): Cu 94–95 & Zn 6–5% (minus allowable impurities 0.13%, which include Pb max 0.03 & Fe max 0.05%). This type of gilding metal is used as casings for primers and detonators for artillery ammunition and bombs

Gilding metal "90/10 Brass" consists of Cu 89 to 91 & Zn 11 to 9% (minus allowable impurities)

There is also gilding metal "98/2 Brass"
Refs: 1) B. Grotta, ChemMetalEngng 26, 1132 (1922) (Gilding metal used for detonator casings contd: Cu 90 & Zn 10%) 2) W. Gardner, "Chemical Synonyms and Trade Names", Van-
Nostrand, NY (1948), p 236

Giles Flask and Its Applications. Giles flask

at \( x \) and \( (x+x/10) \) of its volume, eg, at 500ml
and 550ml. Used in prep ng normal solns (Ref 1, p 376-R)

We are including here the description of use of Giles flask in analysis of mixed acids by aliquot method, as was done by Clift & Fedoroff (Ref 2, Chap I, Part I, pp 1 to 4) at Triton Chemical Corp, Glen Wilton, Va and at Keystone Ordnance Works, Meadville, Pa

THE ANALYSIS OF COMMERCIAL MIXED ACIDS
(Mixtures of Sulfuric and Nitric Acids)
I. Preparation of Aliquot Solution
A. Apparatus:
Separatory funnel with 60° angle and 1000ml
capacity
Giles flask, 1000ml capacity
Support, with ring
Weighing bottle of 15–25ml capacity
Rod with hook to remove weighing bottle stopper
B. Procedure:
1) Arrange the apparatus accdg to Fig GI 5 with the funnel half filled with water (distilled)

2) Shake the sample of acid to thoroughly mix it and transfer 10ml by means of a pipette into a previously tared weighing bottle

3) Weigh the bottle with the contents. Holding the bottle by two fingers of the left hand plunge the upper part of it, including the cover, into water, taking care not to wet the fingers. To prevent the loss of fumes, remove the stopper of the bottle under the surface of the water by
If \( R \) is the burette reading, \( \frac{W}{x} \) is the weight of acid in 100m1 of soln, \( NF \) is the normal factor of the NaOH soln, 49.043 is the equivalent weight of \( \text{H}_2\text{SO}_4 \) (\( \frac{1}{2} \) of mol wt), then the percentage of sulfuric acid as \( \text{H}_2\text{SO}_4 \) is determined by the following formula:

\[
\text{TS} = \frac{(NF) \times 0.049043 \times R \times 100}{W}
\]

III. Total Acidity (TA):
19) Take two 100ml portions of the soln in the Giles flask (see 9) and transfer them into two 400ml conical flasks or beakers
20) Titrate the solns in the same manner as for total sulfuric using Methyl Red indicator

"Note": Methyl Red is partly decolorized by nitrous acid, hence it is advisable to add the indicator towards the end of the titration.

Calculations for Total Acidity in Terms of \( \text{H}_2\text{SO}_4 \):

\[
\text{TA} = \frac{(NF) \times 0.049043 \times R \times 100}{W}
\]

IV. Determination of Nitrosyl-sulfuric Acid
(Nitroso):
21) While the evaporation of the aliquot portions proceeds, take 10ml of the acid sample, using the same pipette that was used for preparing the aliquot soln
22) Transfer the acid to a 400ml conical flask or beaker containing about 100ml of distilled water. (To prevent the heating of the water and the escape of acid fumes the tip of the pipette should be kept in circular motion and held as close as possible to the surface of the water)
23) Run into it from a burette a 0.1–0.2N soln of K permanganate soln until the appearance of the first permanent pink color

Notes:

a) The following reaction takes place during this titration:

\[
2\text{KMnO}_4 + 5\text{HNOSO}_4 + 2\text{H}_2\text{O} =
\text{K}_2\text{SO}_4 + 2\text{MnSO}_4 + 5\text{HNO}_3 + 2\text{H}_2\text{SO}_4
\]
b) If a few drops of sulfuric acid are added to the stock permanganate soln, practically no change occurs in the titer, during several months

Calculations for Nitroso (HNOSO₄):
If \( NF \) is the normal factor of the permanganate soln, and 63.54 is the equivalent weight of HNOSO₄, then
\[
\% \text{HNOSO}_4 = \frac{0.06354 \times (\text{NF}) \times R \times 100}{W}
\]

**Note:** The weight of the mixed acid, \(W\), is the same weight as was used for the 10ml sample weighed in item 3.

**Example for Calculation of a Mixed Acid**

The total acidity as \(\text{H}_2\text{SO}_4\); the total sulfuric as \(\text{H}_2\text{SO}_4\), and the nitrosyl-sulfuric acid having been determined by titration, the \(\text{HNO}_3\) and \(\text{H}_2\text{O}\) are calculated by difference.

**Assume:**

(a) Total Acidity as \(\text{H}_2\text{SO}_4\) = 87.31%

(b) Total Sulfuric as \(\text{H}_2\text{SO}_4\) = 42.11

(c) Nitrosyl-sulfuric = 0.31

then the nitric acid as \(\text{H}_2\text{SO}_4\) (d) is:

\[(d) = (a) - (b) = 87.31 - 42.11 = 45.20\]

and the total nitric acid as \(\text{HNO}_3\) will be (e):

\[\frac{\text{HNO}_3}{\text{H}_2\text{SO}_4} = \frac{63}{49} \Rightarrow \frac{63}{49} \times 45.20 \times \frac{9}{7} = 58.08\]

**Note:** The equivalent weights of 63(\(\text{HNO}_3\)) & 49(\(\frac{1}{2}\text{H}_2\text{SO}_4\)) are taken as close enough for ordinary works practice.

In order to find the actual \(\text{H}_2\text{SO}_4\) and the actual \(\text{HNO}_3\) it is necessary to deduct from the above values the sulfuric and nitric acid equivalents in the nitrosyl-sulfuric acid.

As the molecular weight of \(\text{HNOSO}_4\) is 127 (approx), the \(\text{HNO}_3\) equivalent will be:

\[0.31 \times \frac{63}{127} = 0.15\% \text{ and } \text{58.08} - 0.15 = 57.93\% \text{ actual}\]

the \(\text{H}_2\text{SO}_4\) equivalent will be:

\[0.31 \times \frac{98}{127} = 0.24\% \text{ and } 42.11 - 0.24 = 41.87\% \text{ actual}\]

The results are reported as follows:

| \(\text{H}_2\text{SO}_4\) | 41.87\% |
| \(\text{HNO}_3\) | 57.93 |
| \(\text{HNOSO}_4\) | 0.31 |
| \(\text{H}_2\text{O}\) | -0.11 (by difference) |
| **Total** | 100.00% |

**Refs:**

1) Hackh’s (1944), 376-R

**Girard, Aimé of France prep’d at the end of the 19th century in France the explosive ‘Nitrohydrocellulose’** (See under Hydrocellulose in Vol 7)

**Refs:** Daniel (1902), 342 (Girard, Aimé); 380–81 (Hydrocellulose); 556–57 (Nitrohydrocellulose)

**Girard, Charles of France patented, accdg to Daniel (Ref 1, p 342) and Giua (Ref 4, p 312), nine expl comps contg K picrate, castor oil, MNNaphthalene or charcoal and K perchlorate, or K chloride, or K nitrate. Following are five typical formulations: a) K picrate 4, castor oil 7, MNN 14 & K perchlorate 75% b) K picrate 80, castor oil 10 & charcoal 6% c) K picrate 5, castor oil 6, MNN 9, K perchlorate 45 & K nitrate 35% d) K picrate 4, castor oil 10, K chloride 80 & charcoal 6% and e) K picrate 4, castor oil 6, MNN 11 & K nitrate 79% (FRP 295671, 27 Dec 1899 – 12 April 1900)**

The same chemist patented somewhat later (Ref 1, p 343) four expls contg K chloride or perchlorate with “solidified oil” (huile solidifiée), which was prep’d by adding 100 parts of soap (completely dried at 120–130°), to 15 parts of castor oil and then continuing to heat for 2–3 hrs.
at 150–170°. After filtering the hot liquid it was poured into containers and kept at RT. When required it was heated to 80° and mixed with other ingredients. Giua (Ref 4, p 397), calls this substance "il grasso" and lists the following formulations: a) K chlorate 80 & grasso 20% b) K chlorate 80, grasso 14 & MNN 6% and c) K chlorate 80, grasso 14, Azobenzene 4 & K picate 2% (FrP 295754, 30 Dec 1899 – 18 April 1900).

Four expl comps of Ch. Girard, patented in 1905, are listed on p 398 of Ref 4. They are mixtures of K chlorate with Azodinitrotoluene, with Azodiaminobenzene, with Picroazobenzene and with Azo-p-nitroniline.

An expl compn of Ch. Girard, patented in 1908 in the USA (Ref 2), was prep'd by combining molten Trinitrocresol with PA in molecular proportion to give a low melting compn, and while the mixture was still liquid some K chlorate was incorporated in the above mixtures in order to neutralize the HCl formed during expln and to increase the power of expln.

On p 290 of Ref 4 are listed four low melting expl mixtures of PA with Nitronaphthalene, with DNT and two formulations with Trinitro-m-cresol patented by Girard in 1909 (Ref 3).


Girard, Millot & Vogt studied during the Paris siege of 1870 by the Germans, various absorbents for NG in Dynamites. Among the available substances they found that lump sugar (sucre en morceaux) was a good absorber. They prepared a Dynamite consisting of sugar 60 & NG 40% and found that it was very insensitive to impact. No detonation was produced when a 4.7kg weight was dropped from a height of 1.65 meters.

Ref: Daniel (1902), 343


Vol 6, Part 1, published by UTET in Torino was devoted to explosives on pp 1 to 497 ("Explosivi", in collaboration with Dr Maria Luisa Marchino; to Chemical Warfare Agents on pp 498 to 556 ("Aggressivi Chimici", in collaboration with Dr Marco Civera); and to Matches on pp 557 to 609 ("Fiammiferi" by Dr Leopoldo Stefanine).}

Glacial Acetic Acid (AcOH). An anhydrous acetic acid (See Vol 1, p A25-L) having an ice-like crystalline appearance (fp 16.7°).

Glass of Berlin proposed in 1883 a proplnt prep'd by treating the surface of NC grains with etheralcohol soln, followed by evap of solvent. This gave grains slower burning than untreated NC grains. In later patents (1887), the same inventor treated NC grains with other volatile solvents, such as eth acetate, acetone, etc., and he also added to NC substances like nitrates, chlorates, picrates, naphthalene or paraffin.

Ref: Daniel (1902), 344

Glass and Glass-Blowing. Glass is an amorphous substance, usually transparent or translucent and consisting of silicates, made by fusing together sand and alkalies (such as Na or K) and some base (such as Ca or Pb). Some glasses are borates or phosphates. Glasses may be considered as undercooled liquids of high viscosity. The art of glassmaking has been known for more than 4000 years, and it seems that the Egyptians were the first to produce it.

In order to make articles of various shapes and sizes, glass is melted and then either blown or cast. The glass may also be pressed in the hot state. Venice, Italy has been particularly known for its skillful glass-blowers from the time of the Middle Ages. The art of glassblowing is of great importance to chemical and physical laboratories, and it is expeditious for a laboratory of any size to have expert glass blowers among its staff.

Refs: 1) H. Vigeux, "Le soufflage de verre", Dunod, Paris (1931) (Good book by instructor at Sorbonne; used by senior author during his studies).
3) A. Silverman, "Glass: Historical Notes 1900 to 1950", JChemEd 30, 32-4 (1953) 
9) P. Beyersdorfer, "Glashuettenkunde", (Glass-working Science), VEB (Volkseigener Betrieb), Deutscher Verlag fuer Grundstoffindustrie, Leipzig (E. Germany) (1964) 

Glass in Priming Compositions. It is known that sensitivity of expl mixes to friction (percussion) is greatly increased when a small amt of ground glass [or of other abrasive material, such as sand or carborundum (See Vol 2, p C65-L)] is mixed with the expl

A soft white soda-lime glass is most suitable for incorporation with expts like MF + KClO₄, etc.

Requirements of the US Armed Forces are covered by Specification JAN-G-479 (July 1947) and are as follows:

1) Composition - soft soda-lime glass
2) Workmanship. The glass must be ground with French burrstone or other mills giving the shape, edge and other characteristics of burrstone grinding to the particles
3) Foreign matter. Material shall be free from foreign matter when examined under a low-power microscope
4) Particle shape. When examined under the microscope the fracture of the particles shall be conchoidal and there shall be no long needles or round particles
5) Granulation. When shaken for 5 minutes, either by hand or with a shaker geared to produce 300±15 gyrations and 150 10 taps per minute, the sample should comply with the requirements for class.

The coarsest is Class A: thru No 60 US Std Sieve minimum 100%, retained on No 100 min 99% and the finest is Class E: thru No 170 min 90%, retained on No 200 min 75%

Glass Bulbs for Weighing Acids.

It is important that chemists working in acid laboratories know how to blow weighing glass bulbs and how to use them for taking samples of acids. This method is particularly suitable for sampling fuming acids (such as oleum or fuming nitric) because it avoids release of fumes.

Following is the description given by Clift & Fedoroff, Vol 1 (1942), Chap 1, Part 2, pp 7-8 & 14:

THE ANALYSIS OF OLEUMS INCLUDING THOSE CONTAINING NITRIC ACID

Apparatus:
Nitrometer, preferably duPont (A.H. Thomas Co Cat)

Glass bulbs of about 15mm diameter

Preparation of Glass Bulbs:
Following is a brief description of the manipulation in making these bulbs: Take a piece of soft glass tubing about 5mm diam and heat to redness in a hot tapered flame. Remove from the flame and draw out a capillary about 1mm diam. Break off the end of the capillary and on the other end heat a small portion of the glass to redness (See a, Fig G16). Remove from the flame and blow a small bulb about 15mm diam (See b, Fig G16). A little practice will show how much glass to take for this purpose. It is important to have the capillary uniform and the walls of the bulb thick enough to stand subsequent heating

---

FIG G16

1. TOTAL ACIDITY
1) Weigh up two bulbs, one for a check, with the capillary stems about 7-8cm long
2) Shake the bottle well containing the sample, open it and cover the mouth with a piece of
light lead having a center hole of about 2–3 mm in diam.
3) Heat one of the bulbs gently in the flame of a Bunsen burner and quickly place it in the hole in the lead plate so that the end of the capillary is under the surface of the acid (Fig G17).

![Fig G17](image)

4) While the bulb cools and the acid fills it, prepare a heavy walled conical flask of 500 ml capacity and place about 100–150 ml of distilled water in it.
5) Remove the bulb from the acid, carefully wipe the capillary dry and seal the end by means of the flame. By further heating, bend a hook on the end of the stem for hanging on the balance.
6) Weigh the bulb containing the acid and drop it capillary first into the flask.
7) Break the capillary, with a stirring rod, about 2 cm from the bulb and allow the acid to drain into the water. In the case of strong oleums the action is liable to be violent and the bulb can be held lightly against the side of the flask with the stirring rod.
8) Allow to drain until water has completely replaced the acid in the bulb and any fumes that have been absorbed. Then break the bulb under the water and crush the capillary into small particles.
9) Add Methyl Red Indicator and titrate with sodium hydroxide solution until the color changes from red to greenish-yellow.

Calculations:

\[
\text{% Total Acidity as } H_2SO_4 = \frac{(\text{NF}) \times 0.04904 \times 100 \times R}{W}
\]

where: (NF) = Normal Factor of the NaOH soln
0.04904 = Equivalent weight of H_2SO_4 in 1 ml of Normal soln
R = Burette reading
W = Weight of sample taken

DuPont's nitrometer is described in Vol 1 of Encycl, pp A373 to A396 with Fig on p A374-L. Cleaning of glass parts of nitrometer is described here under "Glass Cleaning and Solvents Used". Preparation of nitrometer for standardization is described on pp A373-R to A374-R and standardization on pp A374-R to A376-R.

Replace "Determination of AN by Nitrometer Method" on p A376-R by the following:

**Nitric Acid in Oleums**

10) Add about 7–8 ml of 85% nitric-free sulfuric acid to a 25 ml weighing bottle, stopper and weigh.
11) Remove the stopper and add a sufficient quantity of oleum to produce 70 divisions of NO in nitrometer. Replace the stopper and weigh the bottle.
12) Shake the contents gently taking care not to smear the stopper and pour the contents carefully into cup (a) of bulb E, shown in Fig on p A374-L.
13) Draw the contents of (a) into E, as described on p A375-L, beginning with the words: "By lowering F and opening f & c draw the contents of cup (a) slowly into E, etc.” up to the words: "Before proceeding with actual measuring of vol of NO evolved" on p A376-L, 12th line from the bottom, proceed as in 14.
14) After transferring the gas into the burette, manipulate A & D until the meniscus in C is even with the top of pasted paper P (See Fig on p A374-L) and the meniscus in D is on the level with it. (Under no circumstances replace compensating tube C).
15) Use Notes on p A376-R.
16) Calculation: \[ \text{% HNO}_3 \text{ in Oleum} = \frac{\text{R} \times 63.02}{100 \times \text{W}} \]

where: R = Reading of buret D in ml and
W = Weight of oleum sample in grams

**Glass Cleaning and Solvents Used.** A brief description is given in Vol 3 of Encycl, p C329-L under "Cleaning Solutions for Laboratory Glassware". A rather complete description is given.
Glass-Feather Manometer. A device for measuring pressures, invented by Schaeffer and Treub (ZPhysikChem 81, 308 (1913) and made in the USA by F.E. Donath, 22 Fourth St, Aspinwall, Penna

This manometer was successfully used by the late Dr E. Berl et al (IEC 10220 (1938)) in modified Will's Stability Test Apparatus

Glass Temperature. Same as Brittle Point or Brittleness Temperature described in Vol 2 of Encycl, pp B302-L to B303-L

Glauber, Johann Rudolph [1603 (or 1604)–1668]. Dutch (or German) "iatrochemist" [belonging to the 16th century school of medicine based on principles of Swiss physician Paracelsus (1493–1541)] who prep'd expl substances Potassium Picate and Ammonium Nitrate. He also prep'd 'the salt known as "Glauber salt"' (cryst Na sulfate) and pure nitric and hydrochloric acid. He also worked with saltpeter and Gunpowder

Refs: 1) Hackh's Dictr (1944), 378 (He gives year of birth as 1603 while Brieger gives 1604) 2) W. Brieger, SS 12, 304–07 (1917), "Johann Rudolph Glauber als-Sprengstoff-Chemiker"

Glazing or Graphiting of Propellants (Lissage ou Plombin des Poudres, in Fr). In order to make a cannon propellant (either black or smokeless), so that it can be blended and poured into containers or cartridges without danger from static electricity, the grains are rendered smooth and glossy by rotating them together with a small amount of powdered graphite in a drum or in a "Sweetie Barrel", such as shown in Davis (Ref 3, p 291). Another purpose of this operation is to render the grains non-hygroscopic. Proplnts which are required to burn quickly (such as rifle and sporting proplnts) do not receive graphite treatment but are rendered smooth by rotating them longer than graphitized proplnts

Glide Bombing. See Vol 5, p D1523-R under "Dive Bombing" and also in Ohart (1946), p 202

Gliding Torpedo GT-1. A 2000-lb aerial torpedo developed by the US Navy during WWII. It was released from a plane at a distance up to 25 miles from a surface target (such as ships concentrated in a harbor or in a convoy)
Ref: Anon, Ordnance 31, 384(1947)

Glossine or Abolite. Accdg to Giu (Ref) it was a Dynamite-type expl patented by F. Abel in 1867: NG 65.5, Collod Cotton 30.0, KNITRATE 3.5 & Na CARBONATE 1.0%
(Compare with Abel Powder described in Vol 1, p A1-R)
Ref: Giu, Trattato 6(1)(1939), 342

Glimite. A mixture of liquid oxygen and finely pulverized carbon which was tried during WWI as a drop bomb charge. The mixture had to be prepd just before flight because it was effective only for a short time after mixing
Refs: 1) T.L. Davis, ArmyOrdn 20, 92 (1939)
2) Bebie (1943), 75

Globular Propellant Powder. An NC in EtAc lacquer is dispersed in an aqueous soln whose temperature is below the bp of EtAc. The suspension is then rapidly blended with 5X its vol of the same aqueous soln under superatmospheric pressure. The combination of temperature and pressure releases the EtAc, and a little w, to instantaneously flash off, leaving spherical particles of the NC behind for centrifugal separation. The process is continuous
(Compare with BALL POWDER, described in Vol 2, pp B11-R to B16-L)

Glonoin. Name for pure NG used in medicine as 1% alcoholic soln, called Spirit of Glonoin, in heart diseases. The usual dose for angina pectoris is 1 drop of spirit taken in water.
Glonoin is also administered in lactose or dextrose pellets, each contg 1/100 grain (0.0006g) NG, by dissolving them under the tongue
Ref: Davis (1943), 208

Gloves, Conductive. The expl industry has been looking for a long time for a glove that would provide al-in-one comfort, hand protection and safety against static electricity.
A new electrically conductive glove made of "Velosrat" is said to be the solution for use during static hazardous operations. The gloves drain off static charges when the wearer is grounded. Chemically resistant, they are claimed to provide protection from acids, alkalies, and other contaminants that can cause injury. Manufacturer especially recommends disposable gloves for those working with flammable solvents, powders, liquids, and dusts
Refs: 1) Velosrat Gloves No 6090, Custom Materials, Inc, Alpha Industrial Park, Chelmsford, Mass, 01824
2) G. Cohn, Ed, Expls & Pyrots 48(8), 1971
Note: "Velosrat" is an acronym for very low static

GLTN. Abbr for Glycerolmonolactate Trinitrate

D-Glucitol (Sorbitol) and Derivatives
D-Glucitol (Sorbitol or Hexanhexol), HOCH2(CH2OH)4CH2OH; mw 182.17, odls (with ½ or 1 w), mp about 110°(dry), 100° or less (with w), very hygr when dry; sol in w & hot alc. Found in various fruits; prepd by sodium amalgam reduction of d-sorbose or by pressure hydrogenation of dextrose with Ni catalyst. Used br prepn of ascorbic acid (Vitamin C), for synthesis of resins, surfactants, agents, varnishes, syrups, cosmetic creams and for explosive Sorbitol Hexanitrate
D-Glucitol (Sorbitol) Nitrato. Sorbitol was nitratated with cold mixed acid, an oil resulting. This exploded on hitting with a hammer. No analysis was reported.

Refs: 1) Beil 1, 533 & (281) 2) C. Vincent & Delachanel, CR 111, 51 (1892)
3) CondChemDict (1962), 1062-L (Sorbitol); (1971), 817-R

D-Glucitol (Sorbitol) Hexanitrate,
O₂NCH₂(CHOH₂)₄CH₂ONO₃; mw 452.16,
N 18.58%, OB to CO₂ +7.1%; tablets (from alc), mp 55.5°C (Ref 1). Prepd in a mixed acid nitratation at ambient temperature of an equi-
parts mixture of sorbitol and glycerol. The resulting oil was stable for 36 min at 80°C in the Abel test, and jelled at -22°C (Ref 2)
Refs: 1) Beil 1, 2391 2) P. Lhoste, MP 40, 103-07 (1958) & CA 55, 3446 (1961)

Gluckauf. An older Ger permissible expl.
Its Formulation AIII coord AN 82.7, DNB 1.0, woodmeal 11.5 & Cu oxalate 4.8%; its power by Trauzl Test was 341cc and charge limit
450g

D-a-Glucoheptose or d-Gluco-a-heptose,
HO.CH₂(CH₂OH)₆CHO; mw 210.18; colorless rhombic prts (from w) or prisms, mp 215°C (dec); solv in w 10% at 20°C and 47.6% at 100°C; solv in boiling alc about 0.3%. May be prepd from the lactose of d-gluco-a-heptonic acid, described in Beil 18, 235 & (419) as γ-Lacton der D-Gluco-a-heptonäsäre (Ref 1)
On nitratation it produces an expl compd: d-a-Glucoheptose Hexanitrate,
O₂N(CH₂(CHOH₂)₆CHO; mw 480.18, N 17.50%, OB to CO₂ +3.33%; colorless ndls (from alc); mp 100°C; reduces Fehling’s soln on warming. Can be prepd by nitrating d-a-Glucoheptose (Refs 2, 3 & 4). It is a powerful expl.

Refs: 1) Beil 1, 934 & (468) 2) Beil 31, 360 3) W. Will & F. Lenze, Ber 31, 68 (1898) 3) J. Leibowitz & S.H. Silman, Ber 58, 1889 (1925) 4) Davis (1943), 244

d-Glucosamide and Its Pentanitrate. Their properties are given in Vol 1, pp A122-R & A123-L, under “Aldonic Acids, Their Deri-

Following procedure, which is a modification of Caesar’s method (Ref 1), was used by Wolfrom et al (Ref 3):

The recrystallized d-gluconamide was slowly added, with stirring, to the chloro-
formic soln of nitrogen pentoxide (either alone or mixed with P₂O₅ or NaF) at -20°C.
Stirring was continued, occasionally, for the next 15 mins, while temp slowly rose to RT.
After allowing it to stand for 35-45 mins, the slurry was filtered and the solid portion was drowned (after allowing the chl to evaporate) in ice water and transferred to a Büchner funnel. After rinsing ppt 3 times with water, under suction, it was dried in a vacuum over P₂O₅. This ppt was purified by dissolving in methanol and adding water to the cloud point. Melting point of dried product was 149°C. It was more stable than d-gluconic acid pentoxide.

Filbert (Ref 2) proposed using nitrated glucosanide in detonators and blasting caps.

Refs: 1) G.V. Caesar et al, USP 2400287 (1946) & JACS 68, 372 (1946) 2) W.F.
Addnl Ref: H. Ficheroulle & A. Kavache, MP 41, 14-18 (1959) (Prepn and props)

d-Gluconic Acid and Its Pentanitrate are briefly described in Vol 1, pp A122-R & A123-L under "Aldonic Acids, Their Deriva-
\textit{tives and Nitric Esters}". Gluconic Acid
Pentanitrate is less stable than Gluconamide Pentanitrate
Refs: Same as under Gluconamide and Its Pentanitrate

Glucopyranose and Derivatives

D-Glucopyranose, \( \text{HOCH}_2\text{CH(CHOH)}_2\text{O} \), mw 180.16. Two forms are known, varying in the configuration of the –CHOH next to the ring oxygenation.

\( \alpha \)-D-Glucopyranose crystallizes from w as monohydrated plates, mp 83–86°, dehydrating below 100°; crystallization from alc, methanol, or 30–35° w (sadt) gives water-free needles, mp 146°. The dry form has sp gr 1.544 at 25°. At 20° 2 g of the dry form will dissolve in 80% alc (100cc) and 0.85 g will dissolve in methanol (100cc). It may be prepd from D-glucose by dissolving the dry form of the latter in w and dissolving with cold HAc.

\( \beta \)-D-Glucopyranose, crystallizes from alc, mp 146–150°, sp gr 1.547 at 13°, sol in 80% alc at 20° of 4.9 g/100 cc. It may be prepd from \( \beta \)-D-glucose by dissolving the latter in w, dissolving with hot HAc, redissolving the precipitate in 0° w, and repptg with alc.


\( \alpha \)-D-Glucopyranose Pentanitrate,
\( \text{O}_2\text{NOCOH}_2\text{CH(CHOH)}_2\text{O} \), mw 405.16, N 17.28%, OB to \( \text{CO}_2 \) +2.0%, crystals, mp 53.5°, exp 250°, sp gr 1.75 at 20°, very sol in eth & methanol; sol in alc. Prepd by nitrating below 0° of the parent in HAc/\( \text{Ac}_2\text{O} \). Loses 60% of weight in 10 hours at 100°.


\( \beta \)-D-Glucopyranose Pentanitrate,
\( \text{O}_2\text{NOCOH}_2\text{CH(CHOH)}_2\text{O} \), mw 405.16, N 17.28%, OB to \( \text{CO}_2 \) +2.0%; crystals, mp 111°, exp 257°, sp gr 1.78 at 20°; sol in alc, eth & methanol.

Prepd by same method as \( \alpha \)-isomer above. Loses 60% of weight in 6 hours at 100°

Ref: See \( \alpha \)-isomer above

Glucosan and Derivatives

\( \beta \)-Glucosan or Levoglucosan (Anhydroglucose),
\( \text{O}_{\text{C}}\text{(CHOH)}_2\text{CH}_2\text{O} \), mw 162.14; rh crystals, mp 178°; sol in w & 90% alc; sl sol in alc. Prepd by heating barium hydroxide soln with p-acetophenyl-\( \beta \)-d-glucopyranoside at 100° for 4 hours.


\( \beta \)-Glucosan-2,3,4-trinitrate or Levoglucosan-2,3,4-trinitrate,
\( \text{O}_{\text{C}}\text{(CHONO)}_2\text{CH}_2\text{O} \), mw 297.14, N 14.14%

OB to \( \text{CO}_2 \)-24.2%; ndls (alc), mp 101° (94–5°, Ref 4). Prepd by the mixed acid nitrating of levoglucosan.


Note: According to E.E. Sancho, "Quimica de los Explosivos", Madrid (1941), p 179, this trinitrate is more powerful than Hexanitroglycerose

GLUCOSE AND DERIVATIVES

D-Glucose (Dextrose or Grape Sugar),
\( \text{C}_6\text{H}_{12}\text{O}_6 \cdot \text{CHO} \); mw 180.16; rhombic ndls (from alc), sp gr 1.544 at 25/4°; mp – 118–20° and then melts at 146–47°; sol in w & alc insol in eth. Can be prepd by the action of HCl on starchy materials, causing incomplete hydrolysis. Used as a reagent for detecting CO in blood; in manuf. of confectionary, production of alcoholic liquors etc.

Gives on nitrating explosive pentanitrate.

Refs: 1) Beil 1, 879 & (443) 2) Hackh's Diet (1944), 379-L & 380-L

D-Glucose Pentanitrate or Nitroglycerose,
\( \text{C}_3\text{H}_5\text{O}_5 \cdot \text{ONOO}_2 \); mw 405.16, N 17.29% (theory); N 16.96% (found); viscous synop which hardens at about 0°; mp <10° (Ref 2); bp – d-comp at 135°; insol in w & in lignin; very sol in alc. Can be prepd by nitrating d-glucose with mixed nitric-sulfuric acid (Refs 1, 2 & 3)

It is an exp which is unstable above 50°
Sancho (Ref 3) lists the following mixture used in Spain: Nitroglose 10, AN 80, K chlo-
rate 5 & coal tar 5%.
Refs: 1) Beil, 1, 897; 31, 146 2) W. Will & F. Lenze, Ber 31, 74(1898) 3) Sancho (1941), 175
4) Davis (1943), 241 5) L. Brissaud, Mém-
Services Chim État 30, 120-32(1943) & CA 41, 715(1947) 6) M.L. Wolfrom et al, JACS 73, 874-5(1951) & CA 45, 5622(1951)

Glucose for Preparation of Sorbitol

Due to large amounts of sorbitol,
$\text{HOCH}_2(\text{CHOH})_4\text{CH}_2\text{OH}$, being required during WWII for the prep of ascorbic acid (Vitamin C),
a method was developed by Tertamanzi & Arnaldi (Ref) for the prep of sorbitol by the hydrogena-
tion of glucose. Their method required smaller
amts of catalyst, lower temperatures, lower pressures and shorter time than previously described
methods.

[See also D-Glucitol (Sorbitol) and Derivatives]
Ref: A. Tertamanzi & N. Arnaldi, Atti AccadSci-
Torino 77, 271-77(1942) (An abbreviated transn
is available at PicArsn Library)

Glucose-Glycerol and Lactose-Glycerol Nitrates.

Solutions of glycerin with either grape sugar
(glucose) or milk sugar (lactose) produce on
nitration compounds similar to nitrated glycerin-
sucrose mixtures, suitable for use in low-freezing
dynamites.

Glucose dissolves in glycerin more readily
than sucrose and sucrose more readily than lactose.

Glucose dissolves in glycerin to the extent of
about 40 parts in 60, but for the reason of stability
it is better to use a mixture of 20p of glucose and
80p of glycerin. Such a mixture yields on nitra-
tion an oily compound with $N=18.20\%$ and con-
sisting of Glucose Pentanitrate and NG. This
mixture does not differ appreciably in expl strength
from that of straight NG.

Lactose-glycerin solution on nitration yields
a mixture of lactose octanitrate, $\text{C}_{12}\text{H}_{14}\text{O}_{5}(\text{ONO}_2)_5$, and NG.

Ref: Naoum, NG (1928), 256

Glucosides and Glycosides. Glucosides are compds
of glucose with some other substances: There are
methyl-, ethyl-, etc ethers of glucose, which occur
in many plants. They belong to glycosides, which
are compds of sugars with other substances. Compds
of fructose are known as fructosides and of galac-
tose are galactosides. Glucosides treated either
by heat, dilute acid, enzymes, bacteria, or fungi,
yield glucose, while fructosides yield fructose
and galactosides give galactose. There are alpha
and beta glucosides.

Refs: 1) Hackh's Dict (1944), 380-L (Glucoside);
384-L (Glycoside) 2) CondChemDict (1971),
423 (Glycoside)

Glucosides, Nitration Studies were conducted
during WWII by M.L. Wolfrom and described in
OSRD 147 or PBA 31201(1941), entitled "The
Preparation of Sugar Alcohols and Glucosides
for Nitration Studies"

An example of glucosides is:
$a$-Methyl-$d$-glucopyranoside Tetranitrate,
$\text{O}_2\text{HOC}_2\text{CHO}_2[\text{CH}(\text{ONO}_2)_2]$CHOCH$\text{O}_2$; mw 374.18,
N 14.97%, OB to $\text{CO}_2$ -21.4%; plates (alc), mp
49-50°, dec 135°. Prepd by dissolving $a$-methyl-
glucoside in cold nitric acid (sp gr 1.52), followed
by dropwise addition of cold concd sulfuric acid
at 0°.

Refs: 1) Beil 31, 182 2) W. Will & F. Lenze,
Ber 31, 80(1898) 3) L. Brissaud et al, MP 33,
187(1951) 3a) L. Méfard, MP 33, 193-98(1951)
4) D. O'Meara & D.M. Shepherd, JCS 1955,
4232-35 & CA 50, 10655(1956) (They prepd several
nitrated derivs of glucoside, but only the tetra-
nitrate was expl)

Glucoside Nitrate in Mixture of Nitrated Poly-
ethylene glycol was described by R.C. Moran in
CanadP 275876(1927) & CA 22, 1687(1928)

Glues. See also under "Gelatin and Glue", this
Vol, p 443-R & 444-L

Animal (Colla): Impure gelatinous matter of ani-
mal origin, most commonly bone glue made from
hides and bones, casein glue made from skimmed
milk, and fish glue made from fish skins|Hackh's
Vegetable: A gelatinous mass obt'd from different plants, the best being Acacia glue or Gum arabic prpd from gummy exudations of the Acacia senegal. Glue known as albumen may be prpd from flour in starch manufacture. There are also glues prpd from agar-agar, dextrin, starch, potato flour, etc. Some are used in the expl industry, either as bonding agents or to increase the plasticity of expls. For instance, dextrin and gum arabic are used in some primer mixtures.

Dextrin, starch, potato flour and the so-called gum sugar which is a syrupy, sticky and non-crystallizing soln of sugar in glycerin were patented by Dynamit AG of Germany for increasing the plasticity of dynamites inexpensively [Naoum, NG (1928), p 406]. Same author also cites on p 351 a method of prpn of Gelatin Dynamite in which glue was used [GerP 17Z651 (1905) issued to Schachtbeck].

Glue-Gelatinos. Compounds such as "Melan" (See under) were used for the prpn of plastic dynamites, partly replacing gelatinized NG.

Glue, Nitratied. Daniel (1902), p 520) describes one of the methods of nitration of glues. For this he advises heating the glue with a small amount of dil nitric acid until dissolved, then gradually adding mixed acid with stirring; the product is washed and dried.

Glues Used for Military Purposes (US Specifications). Some of the adhesives, binders & glues used for military purposes are as follows:

- Adhesive and Sealing Compounds, Cellulose Nitrate Base, Solvent Type (For Ordnance Use); US Spec MIL-A-82484 (June 1967)
- Adhesive MR-23 (For Use in Ammunition); US Spec MIL-A-50926(1) (April 1972)
- Adhesive, Dextrin (Spinal Tube Winding for Ammunition Containers); US Spec MIL-A-13374C (June 1969)
- Adhesive Paste, For Demolition Charges; US Spec MIL-A-374A (Jan 1953)
- Adhesive, Phenol and Resorcinol Resin Base (For Marine Service Use); US Spec MIL-A-22397 (Sept 1960)

Adhesive, Silicone Rubber for Igniter Mark 265; US Spec MIL-A-23940 (Sept 1966)
- Binder, Cellulose Nitrate (For Pyrotechnic Mixtures); US Spec MIL-B-1085A (Jan 1951)
- Glue, Animal (Protective Colloid); US Spec MIL-G-40630C (Oct 1972)
- Glue, Marine, and Aviation Marine (Waterproof); MIL-G-413B (Oct 1963)
- Gum, Arabic (Gum Preservative or Gum Acacia); US Spec JJJ-G-821. Used as an adhesive, bonding agent, fuel and retardant in pyrotechnics Source & props are given in AMCP 706-187 (Oct 1963)
- Gum Tragacanth (For Use in Ammunition); US Spec JAN G-96A (Aug 1969). Used as a bonding agent & fuel in pyrotechnics. Source & props are given in AMCP 706-187 (Oct 1963)

See also Adhesives in Vol 1, p A102-R; Binder or Agglutinant in Vol 2, p B120-R; and Bonding Agents or Adhesives for Ordnance in Vol 2, p B242-L.

Glug & Slug-Units of Mass

Concern was expressed by David (Ref 2) about the possibility that a new unit of mass, glug, suggested by Price (Ref 1), might prove confusing, but, in the opinion of Dunkle (Ref 3), it should not be. As long as we have slug, why not the glug?

If we let \( g \) represent unit acceleration, the new unit can be expressed as:

\[
1 \text{ glug} = 1 \text{ g} \frac{\text{gram-force}}{\text{g}} = 1 \frac{981 \text{ dynes}}{1 \text{ cm/sec}^2} = 981 \text{ grams-mass},
\]

just as in the English system:

\[
1 \text{ slug} = 1 \frac{\text{pound-force}}{\text{g}} = 32.2 \frac{\text{pounds}}{1 \text{ ft/sec}^2} = 32.2 \text{ pounds-mass}.
\]

2) A. David, Ibid 26, 41 (1958)
3) C.G. Dunkle, Ibid 26, 503 (1958)

Glukodino. Acqcdg to Daniel (Ref 1), it was a liquid expl prpd at the end of the 19th century in Sweden by C.G. Björkman by nitrating a sa-
turate soln of sugar in glycerine. This mixture was proposed by Ditmar to be used in mining expls: a) Glykodine 36.40 (NG 33.19 & NSugar 3.21), sugar 8.40, Na nitrate & chlorate 31.20 & NC 23.36 parts
b) Glykodine (NG 30.23 & NSu 4.03), sugar 8.76, Na nitrate & chlorate 37.84 & charcoal 19.31 parts. These expls are called by Sancho (Ref 2) “Explosivos de Björkman” (Compare with “Björkman Explosive”, described in Vol 2 of Encycl, p B165-L).

Refs: 1) Daniel (1902), 345  2) Sancho (1941), 181-82

Glutaric or Pentanedioic Acid (n-Pyrotartaric Acid), COOH(CH₂)₃COOH; mw 132.11, colorless, crysts, sp gr 1.429 at 15°, mp 97.50, bp 200° at 20mm; sol in w & in benz; ver sol in alc & in eth. Can be prepd from cyclopentanone, CH₃(CH₂)₃CO. Used in org synthesis.


Glutaric Acid Diazide, H₂C(CH₂CON₈)₂; mw 182.14, N 46.15%; clear, pungent liquid oil, explodes on heating even under w. Prepd from the dihydrazide hydrochloride salt in eth with sodium nitrite.


Glutaricacidglycine and Derivatives

Glutaricacidglycine or Glutarylglucose, HOOCC(CH₂)₃CONHCH₂COOH; mw 189.17. There is no reference to this compound in the open literature.

Refs: 1) Beil, not found  2) CA, not found

Azidoglutaricacidglycine Azide, N₃CO(CH₂)₃CONHCH₂CON₈; mw 233.20, N 41.00%; thick oil, explodes in a flame. Prepd from the corresponding dihydrazide and nitrous acid at 0°.


Glyceraldehyde (dl) or Glyceric Aldehyde (dl), (also called Glyceryl Aldehyde), HO.H₂C.CH₂OH; CHO; mw 90.08; colorless, tasteless crysts (from alc-eth mixt), sp gr 1.455 at

HN.C₂H₄N(O)₃; mw 126.12, plates (from w), mp 300°(dec); sl sol in alc & hot w; insol in usual solvents. Prepd by boiling with soln β-hydroxy-β-amino-glutaric acid ethyl ester amide, or by heating at 130° 2,4,6-trihydroxypyridine and ammonium acetate.

Refs: 1) Beil 22, 511 & (656)  2) H.N. Stokes & H. von Pechmann, Ber 19, 2696, 2705 (1886)

Azidoglutamine. There is no reference in the open literature to a compd corresponding to a mono- or a diazidoglutamine.

Refs: 1) Beil, not found  2) CA, not found

Nitroglutazine or 3-Nitro-4-amino-2,6-dihydroxypyridine, mw 171.11, N 24.56%; om-yel plates (from w), dec 170-80°. Prepd from glutazine and nitrous gases in cold w.

Refs: 1) Beil 22, 512  2) H. von Pechmann, Ber 20, 2656 (1887)

Dinitroglutazine or 3,5-Dinitro-4-amino-2,6-dihydroxypyrindine, mw 216.11, N 25.93%; OB to CO₂ -44.4%; yel plates (from w), dec on heating. Prepd from glutazine and nitrous gases in cold w.

Refs: 1) Beil 22, 512  2) H. von Pechmann, Ber 20, 2656 (1887)

Gluten. A yellowish to gray pdt, or a gray brown sticky tough mass that is insol in w, sol in alkali and in strong AcOH. It is a mixt of proteins usually derived from corn or wheat, but applicable to similar material from other grains, such as rye, oats, etc. Gluten is the protein present in flour and bread. Used in certain breakfast foods, for adhesives, for prepn of amino acids and as an ingredient (in lieu of cereal meals) of some mining expls, such as Ammonodynium.

Ref: CondChemDict (1961), 540-L; (1971), 420-L

Glutol or Glutoform. See under Formaldehyde-Starch Mixtures, this Vol, p F167

Glyceraldehyde (dl) or Glyceric Aldehyde (dl), (also called Glyceryl Aldehyde), HO.H₂C.CH₂OH; CHO; mw 90.08; colorless, tasteless crysts (from alc-eth mixt), sp gr 1.455 at
**G 87**

18/18°, mp 142° (145°), bp 130° at 0.8 mm; sl sol in w, alc or eth; insol in benz, petr eth or petroleum.

It is produced by oxidation of sugars. Used in adhesives, as cellulose modifier, leather tanning and in prep. of polyesters.


**Glyceride.** An ester of glycerol and fatty acids in which one or more of the hydroxyl groups of the glycerol have been replaced by acid radicals. Glycerides occur in nature and can be made synthetically. The most common ones are based on fatty acids and occur in oil and fats. Mono- and triglycerides are of commercial importance.

(See under Glycerols)


**Glycerin(s).** Same as Glycerol or Glycerol Trihydrate. Not to be confused with glyceryl or propenyl, which is trivalent radical, \(-H_2C.CH.CH_2-\), derived from glycerol.

**Glycerol.** Same as Glycerin

**Glycerron.** A colorless, viscous glycerin-like liquid developed in Germany during WWII as a substitute for glycerol which was then in short supply. It was produced commercially by IG Farbenindustrie AG. The process was described in detail by Sheely (Ref 1). The mix produced by IG Farbenindustrie by continuous catalytic hydrogenolysis of sugar at 200° & 325 atm consisted of 35% glycerol, 35% glycols and 25-35% of hexitols (hexols) with some other compounds. It was used in cellulose films, sausage casings, printing pastes, pharmaceuticals, etc and its nitrate product was used in lieu of NG in Dynamites (Refs 1 & 3)

Acetox to Ref 2, in the German process a 70% aqueous soln of sugar, contg 0.1% oxalic acid and 5 parts of Ni catalyst per 100p of dry sugar, was heated at 70° for 4-5 hours.

The resulting inverted sugar was hydrogenated at 200° and 300-325 atm, which yielded a mix of 40% glycerol, 40% glycols (mostly propylene glycol) and 20% of nonvolatile hexols (C6 alcohols). On nitration this mixture gave an expl nitrate which was too unstable for military purposes, but suitable as an ingredient of Dynamite and other commercial explosives.


**GLYCEROL OR GLYCERIN AND DERIVATIVES**

Glycerol or Glycerin (Glycol Alcohol, Propenyl Alcohol or Glycerol Trihydroxide)/Glycéine in Fr, Glycerin or Glycerin in Ger, Glicerina in Itat or Span, Glitserin in Russ, and Guarz in Japan), CH(OH)(CH_2 OH) not mw 92.09, sp gr 1.260 at 20/4° and 1.265 at 15/15°, mp 17.9°, f p 0° (with supercooling), bp 290°.

First isolated by Scheele in 1783, glycerol is a sweet tasting, extremely hygroscopic liq.; sol in w and in alc.; insol in benz, chf, CS2, CCl4, eth, petr eth, and oils; the heat of combustion is 397.2 kcal/mole.

**Preparation**

There are several methods for the preparation of glycerol:

1) Recovery from the spent lye liquor ord. on saponification of fats and oils in the soap industry.

2) Fermentation of sugar process developed in Germany during WWII, giving the so-called "Protol" glycerin.

3) Preparation from propyl alcohol developed during WWII by IG Farbenindustrie at Oppau, Germany (the so-called "Oppau Process")

4) The Shell Chemical Corp synthetic method (Ref 5) from cracked gases containing propylene, which goes thru the following stages:

\[ CH_3.CH.\text{CH}_2 \xrightarrow{\text{Cl}_2 \text{H}} \xrightarrow{\text{Cl} \text{HCH.CH}_2\text{OH}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{Cl}} \xrightarrow{\text{heat}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{OH}} \xrightarrow{\text{NaOH}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{OH}} \xrightarrow{\text{Cl} \text{HCH.CH}_2\text{OH}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{Cl}} \xrightarrow{\text{Cl}_2} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{Cl}} \xrightarrow{\text{Nal} \text{OH}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{OH}} \xrightarrow{\text{CH}_2\text{HCH.CH}_2\text{OH}} \]
It is also possible to treat allyl chloride with HOCl, transforming it to glycerin dichlorohydrin which, on action of NaOH, yields crude dilute glycerol consisting of a mixture of glycerol and NaCl in water. Final steps in the process are those of concentration, desalting and purification.

The major use for glycerol is to form esters with phthalic anhydride to make alkyd resins; other major uses are in cellophane, drugs and toilet goods, tobacco, and, much less now that EGDN use has increased, in NG (requiring a 99% purity grade called "dynamite glycerin").

Note: According to Marshall (Ref 2), glycerol prep'd by fermentation of sweet liquors might contain some trimethylene glycol, CH₂(CH₂OH)₂, which being of lower density (1.055 at 20/20°) will lower the density of the glycerol. This impurity is not harmful as it gives a stable exp'd dinitrate on nitration. However, as the latter is more sol than NG and is more unstable in contact with acids, lower yields are obtained.

General Refs on Glycerol:

1) Beil, 1, 502, (266), [575] & [2297]
2) Marshall 1 (1917), 201; 2 (1917), 703-706;

Glycerol Analysis

In testing glycerol, it should be remembered that it is very hygroscopic and has to be kept in well-stoppered containers. The requirements of the US Armed Forces for "Dynamite Glycerin" or "High-gravity Glycerin" (also known as Grade B) are covered by Federal Specification O-G-491 and are as follows:

1) Appearance. It shall be clear and free from suspended matter when examined by transmitted light.
2) Color. Maximum limit shall not be darker than a combination of No 80 yellow Lovibond glass and No 8 red Lovibond glass with a 5½ inch column of glycerol. The test may be made by placing the sample in a colorimeter tube to a depth of 5½ inches and comparing the color with an empty tube plus the two Lovibond glasses placed above or below the tube.
3) Odor. Shall be slight and characteristic of the grade of glycerin specified. Compare with the sample agreed upon.
4) Specific Gravity. Shall be not less than 1.2620 at 15.5/15.5°. Any method that is accurate within two points in the 4th decimal place may be used. The most convenient is the pycnometer method (see Vol 3 of Encycl., p D69-L).
5) Acidity or Alkalinity. When 50ml of glycerol is mixed with 100ml of distilled water which has been freshly boiled and cooled (CO₂-free), and about 0.5ml of phenolphthalein indicator (5g dissolved in 1 liter of 50% alcohol), the soln shall not require more than 0.3ml of normal HCl or more than 0.3ml of normal NaOH soln for neutralization. It is more convenient to use approx 0.5N solns and multiply the results by the normality.
6) Ash. Shall not exceed 0.01%. For this test, a 5g sample is weighed on a triple-beam balance into a dish, previously tared on an analytical balance, and heated over a free flame until the vapors continue to burn after removing the flame. (During the operation the sample should be protected from drafts). When the combustion dies out, ignite the residue at low red heat (or in a muffle furnace at 800°) until the carbonaceous matter is consumed, then cool in a desiccator & weigh.

\[
\text{% Ash} = \frac{\text{Wt of residue}}{\text{Wt of sample}} \times 100
\]

7) Chlorides, calculated as chlorine. Shall not exceed 0.01%. For this test, add about 25ml of hot distilled water to the ash residue and rub with the flattened end of a stirring rod. Add 1 ml of K chromate indicator (10g in 100ml water) and titrate with 0.01N Ag nitrate soln (1.7g pure AgNO₃ in 1 liter water) to the first
permanent reddish tint. Run a blank denm on the reagent and make the correction

\[
\text{% Chlorides as } Cl_2 = \frac{\text{ml } AgNO_3 \times N \times 3.546}{\text{Wt of sample}}
\]

Besides the tests described, the following tests may be used if desired:

8) **Moisture.** As water is strongly retained by glycerol, it is difficult to obtain correct results glycerol dehydration methods: drying a thin film of glycerol over concd sulfuric acid in a vacuum desiccator or by heating the film at 90° on a water bath to constant weight, as described in Naoum (Ref 1, p 32), or by a method described by Laurie (Ref 2, p 259). More reliable results are obtained by using Carl Fischer's method or by distg glycerol with tetrachloroethane as proposed by T. Berth (Ref 3) and modified by Riesener & Kessen (Ref 4) (See Vol 5 of Encycl, pp D1620-L to D1628-L). Moisture may be calculated after determining the sp gr of the sample (See Table under tests by Hercules methods).

Following are the tests used by Hercules Powder Co, Wilmington, Delaware:

1) **Color:** Note the color and report in terms of "light straw", "straw", or "dark straw"

2) **Odor:** If it does not smell bad, report "no bad odor"; otherwise describe the odor present

3) **Specific Gravity and Moisture Content:**

   Determine the sp gr by means of a 50ml pycometer at exactly 15.6°/15.6° or determine it at other temps and calculate for 15.6°/15.6° as follows:

   \[
   \text{Sp Gr at } 15.6°/15.6° = \frac{G}{C} \times \frac{1}{1 + a(e^t - 15.6°)} + B(e^t - 15.6°)
   \]

   where: \(G\) = Grams of glycerol at \(t°\)

   \(C\) = Capacity of pycometer in grams of water at 15.6°

   \(a\) = Coefficient of expansion of glass, 0.000025 per 1°C

   \(t\) = Observed temperature, °C

   \(B\) = Change in sp gr per 1°C:

   0.00061 between 15.6° and 20°,

   0.000615 " 20 and 25°,

   0.00062 " 25 and 30°

**Note:** The advantage of making the sp gr denm at \(t°\) (such as RT) rather than at 15.6° is that the bath can be kept at a constant temp more easily at somewhat higher temps. Moreover, if the denm were made at 15.6°, the moisture condensing from the air on the surface of the pycometer would not allow its being weighed until it assumed RT.

Bosart and Snoddy (Refs 5 & 6) give a table of specific gravity vs % glycerol content for aqueous solns. A more detailed table is given in Hercules Manual (Ref 7), which is not reproduced here.

4) **Acidity or Alkalinity.** The test is similar to the one described above (taken from Federal Specification O-G-49).

**Note:** The presence of fatty acids may be determined as follows: Add 10 ml of water to 250ml beaker about 200ml of water and place a pin-head size grain of camphor on the surface. (The beaker should be perfectly clean (greaseless) and should not be touched on the inside with the fingers). If the water is free of grease, the camphor will start to move in a rotary manner. Add a few ml of the glycerol to be tested and observe the behavior of the camphor. If it stops and remains motionless, it indicates the presence of fatty acids. Mineral oils are without effect.

5) **Ash.** Same test as in Spec O-G-49, described above

6) **Chlorides as Chlorine.** Same test as in Spec O-G-49, described above

**Note:** As chlorides such as NaCl are volatile, part of them may be lost during the heating of carbonaceous residue either with a burner or in a muffle furnace, as in the test of Spec O-G-49. More accurate results may be obtained if the burning is carried out only to the carbon and not to the ash. In this case proceed as follows:

   Over a Bunsen burner, heat a tared porcelain or platinum dish containing 50g sample of glycerol until the vapors ignite after withdrawal of the flame. Allow the combustion to proceed without further heating until the flame dies out. Cool the dish, add 25ml of water and heat with stirring to almost boiling, then filter thru No 2 Whatman paper. Cool the soln to RT and titrate to the first permanent red color with 0.01N Ag nitrate in the presence of five drops of saturated K chromate indicator.

**Authors' Note:** It is much easier to obtain a correct endpoint if the titration is carried to
a distinct red color and then back titrated to a yellow color by using 0.01N KCl soln
7) Water. Karl Fischer Method is used (See Vol 5 of Encycl, pp D1622-L to D1628-L)
Nitration Test: The "dynamite glycercin" might pass all the chemical and physical tests and still possess properties undesirable in the manuf of NG, such as slow separation from mixed acid, formation of emulsions and poor settling during washing, poor yields etc. For this reason a trial laboratory nitration of glycercin with exact dem of NG is of great value. The comp of mixed acid and the method of nitration should follow plant practice as closely as possible.

When dem of yield is required, use a large sample of glycercin (about 100g) and Method No 1, which is conducted in an open lead casserole of about 1 liter capacity using for an agitator a thermometer inserted in a lead pipe with a slot for reading.

Nitration can also be done in a glass nitrating funnel as described by Naoum (Ref 1, p 34)
Method 1 (Laboratory)
Procedure:
The nitration must be conducted under a hood and behind safety glass. Avoid smelling of acids of resulting NG
1) Place the nitration (lead casserole of 1 liter capacity) into a large earthenware dish contg a cooling mixture of ice and large crystals of common salt
2) Charge the nitration with 600g of acid contg 49-50% HNO₃ and 52 to 53.5% H₂SO₄ and cool it to about 10⁰(50°F), using the armored thermometer for stirring
3) Weigh into a small tared separatory funnel about 100g of glycercin
4) Attach the funnel above the nitration in such a manner that the tip of the tube is a few inches above the surface of the acid
5) Open the stopcock of the funnel with one hand and allow the glycercin to flow in a small stream into the acid
6) Continue to agitate the acid by means of the armored thermometer held in the other hand
7) Watch the temp closely and, as soon as it approaches 15⁰, reduce the flow of glycercin in order not to exceed 15.5⁰(60°F)
8) By regulating the flow of glycercin, try to keep the temp range between 13 & 15⁰
Note: If the temp rises above 15⁰, stop adding the glycercin. If the rise in temp is fast with evolution of copious brownish-red fumes, drain the mixture in at least 5 liters of water in a beaker or casseral. Never dump into the sink
9) After all the glycercin has been added, continue the agitation for about 2 mins
10) Remove the nitration from the cooling dish and transfer the acid-NG mixt to a 1000ml separatory funnel
11) Wash the nitration with a small amount of fresh mixed acid and transfer the washings to the funnel
12) Let the mixt stand for 30 mins and run the acid layer into a 500ml separatory funnel
13) Leave the NG in the large separatory funnel and slowly add to it about 100ml of cold distd water
14) Insert thru the top opening of the funnel a small glass tube connected to the compressed air system and agitate the mixt, water-NG, for 5 mins
15) Allow to settle and run the NG into a small flask and the acid water into a larger one
16) Transfer the NG to the above 1000ml funnel and repeat the operation of washing, agitation and separation twice. The temp of the water should be about 30⁰ for the second and about 40⁰ for the third wash
17) Next wash with 100ml of about 3% aqueous Na₂CO₃ at 40⁰, agitate for 10 mins, separate and finally wash with 100ml of concd NaCl soln at 40⁰
Note: As NG is appreciably soluble in water, care should be taken not to use too much water. In order to have comparable results, the same quantity of water should be used for all dems (Ratio 1:1)
18) Collect all the wash waters into a large separatory funnel and let them stand overnight in a cool place for further separation
19) Transfer the washed NG, slightly turbid due to the presence of moisture, to a tared dish and place it in a Ca chloride desiccator
20) If the liquid becomes clear, weigh the dish the next day, otherwise continue drying
21) The separation of small amounts of NG left in the acid and wash waters is usually
done the next day
22) Run the acid out of the 500ml funnel and wash the surface of the remaining NG in the funnel with a small amount of water without stirring the mix
23) Run this NG into a small tared dish and weigh it. Deduct 10% from the weight to allow for the presence of some acid
24) There might be drops of NG stuck to the sides of the separatory funnel containing the wash waters. By using a rubber policeman on a glass rod, these drops can be collected on the bottom and drawn off into a small tared dish, dried over CaCl₂ and weighed.
25) The combined weights of NG (20, 23 & 24) give the total NG obtd.

Calculation:

% Yield = \( \frac{\text{Total Wt of NG} \times 100}{\text{Wt of glycerol taken}} \)

When glycerol is nitrated for use in military smokeless propellants, the main requirement is usually not the yield of NG, but its stability and other properties, as required by the specifications. If this is the case, a smaller sample can be used (10g), but the nitrating acid should be prepared from technical acids used in the plant and not from cp acids.

Following is a procedure originated by Hercules Powder Co and adopted at Picatinny Arsenal with slight modifications. All operations should be conducted behind safety glass.

Reagents:

Nitroglycerin Mixed Acid. Use a mixed acid from a regular lot of acid used in the plant nitration of glycerol and which meets the current requirements for this acid.

Sodium Carbonate Solution. Dissolve 10g of sodium carbonate in 90ml of distilled water.

Apparatus (See accompanying Figure G18)

A. 1 x 7-inch centrifuge tube immersed to half its height in an ice-water bath held in a 2-liter container E and held in place by a rubber covered clamp.

B. 50-ml dropping funnel graduated or marked so as readily to indicate the delivery of 10g glycerol, and having a stem so bent and drawn out as to drop the glycerol directly onto the acid over 20-25 mins.

C. Thermometer reading 30-120°F with bulb just under the acid surface.

D. 5-mm glass tubing drawn down to 1-mm and angled at the end so that the tip is near the bottom of the tube, serve as an air agitator.

E. 2-liter container for ice-water bath (Not shown in Fig G18)

F. 100-ml separatory funnel with short stem, to serve as separator of NG from the spent acid.

G. 1000-ml tall form beaker.

H. Two 250-ml graduated cylinders.

I. Two 50-ml conical separatory funnels having short rubber tubing with pinchcock closures instead of glass stopcocks.

J. Ring stand.

K. Pair of pliers.

L. Pair of canvas gloves.
Procedure:
Transfer 80g of mixed acid to A and lower into the ice bath so that the acid and bath levels coincide, the thermometer and agitator are positioned as indicated above, and the dropping funnel stem is about 1 inch above the acid. Using vigorous agitation cool the acid to 45-50°F, then start adding the glycerol at 1 drop/10 seconds onto the point of greatest agitation, proceeding thusly until the 10g of glycerol has been added, providing that the temp does not rise above 60°F and that no red fumes appear. Should either of these indications occur, immediately cease the flow of glycerol. This action not proving to have the desired effect, don gloves, break the agitator above the reactor with pliers and then lower the reactor until it may be tipped to drown the contents in the bath. Then leave the area promptly.

Note: Amt of less than 80g mixed acid per 10g glycerol tends to give an explosively unstable spent acid.

On completing a normal reaction, raise the funnel out of the way, and transfer the thermometer and agitator to the 1000-ml beaker containing 750ml of cold water.

Pour the spent acid–Nitroglycerin (NG) mixture into a 100ml separatory funnel (F) and allow to stand until a good line of separation is observed. Rinse the nitrating tube, immediately after employing, by filling with cold water, pouring this rinse water into the beaker containing the thermometer and air tube. Withdraw the spent acid in the 100-ml separatory funnel thru the stopcock into a beaker.

Note: This stopcock must be greased after each use and securely held in place by a suitable means.

Transfer the NG thru the stopcock, to a 250-ml graduate containing 10ml of water, and place the graduate and contents in a water bath. Insert the thermometer and agitator assembly used in the nitrification into the graduate and agitate by passing air thru the charge for 10 minutes maintaining the temp of the charge at 110°F. Pour the charge into a funnel fitted with a piece of rubber tubing and a clamp and allow to settle for 10 minutes. In the meantime decant the water in the liter beaker and transfer any NG present to the charge in the funnel.

Note: Do not pour the wash water into a sink.

Insert the thermometer and air agitator assembly into a 250-ml graduate containing 10ml of 10% soda ash (sodium carbonate) soln and agitate the soln. Transfer the NG to the graduate and agitate the mixture for ten mins at 110°F. Pour the charge into the funnel fitted with rubber tubing and after separation takes place, test the soda ash wash water with phenolphthalein paper. If the water is not alkaline, repeat the wash with soda ash soln. Allow the charge to settle for 30 minutes, then filter the NG by means of a funnel fitted with four thicknesses of Whatman No 41 filter paper or equivalent. The NG should now be clear; if not, repeat the filtering operation. Determine the pH value of the NG in accordance with the method described below. If the pH value is not within the prescribed limits, rewash with water or soda ash as required.

Collect NG in a rubber-stoppered bottle and save for testing.

Tests for NG:
Nitrogen Content

Determine the nitrogen content by duPont-Lunge nitrometer as described in Spec JAN-N-246 and in Vol 1 of Encycl, pp A373 to A376.

It is described here as Test 4.3.3:
Determination of Nitrogen in NG, under Test Methods and Procedures. Test 4.3.3.1 is "Standardization of Nitrometer", while Test 4.3.3.3 is the "Procedure with Nitrometer".

Calculation

As the sample of NG was dried only by filtering thru paper, it is assumed that it still retains an average moisture of 0.17%. By introducing a factor 0.9983 in the equation:

\[ \% N = \frac{\text{Nitrometer Reading}}{0.9983} \times \text{Wt of sample} \]

the nitrogen content of the dry NG is arrived at. Minimum for \( \% N \) is 18.40.

Stability of NG by KI Test at 82.2±1°F (Abel Test)

Conduct the test in the same manner as called for by the Abel Test with the exception that a temp of 82.2±1°F is maintained. The test is described in Specification JAN-N-246B.

Minimum requirement is 10 mins as Test 4.3.4, entitled "Determination of Stability of NG", which follows the Test 4.3.3.3, "Procedure with Nitrometer".
Note: Although Spec JAN-N-246 allows a minimum of 10 mins, a minimum of 15 mins is preferred, and, if possible, should be attained. However, if the sample has a KI test at 82.2°C lower than 15 mins plus but greater than 10 mins plus, the lot may be accepted.

Neutrality Test:

The usual method of testing neutrality by means of litmus or phenolphthalein paper is not applicable when the pH of the material is around 7.0. Litmus paper does not turn red until the acidity is between approx pH 4 and 6, and phenolphthalein paper does not change color until the acidity is between approx pH 8 and 10.

As freshly washed NG should show a pH of at least 7.0, the most accurate method for this test is by means of a pH meter. However, if no pH meter is available, a colorimetric method based on the use of La Motte indicators supplied by La Motte Chemical Products Co of Baltimore, Maryland is recommended. This method is rapid and accurate to at least ± 0.05 pH unit.

Procedure:
Prepare in advance about 10ml of water with pH exactly 7.0 by neutralizing distd water with NaOH. For testing the water, use a pH meter or the La Motte colorimetric method. Store the water in a Pyrex bottle with a ground glass stopper. If the colorimetric method is used, proceed as follows:

By means of a graduated pipette provided with a rubber suction bulb, transfer 2ml of NG to a La Motte Co comparator tube and add neutral water to the mark on the tube. After this, add 0.5ml of La Motte Co bromthymol indicator, close the comparator tube with a clean cork stopper and shake.

Compare the color of the soln with the standards provided with La Motte Block Comparator.

The color should be between standards of pH 6.9 and 7.1. However, some plant practices permit a pH of 7.8.

Destruction of Waste NG:

Any NG left after tests or in waste waters should be mixed, by means of a hard rubber spatula, with sawdust in a waste bucket and sent to the burning grounds. All the apparatus which contained NG should be cleaned with acetone and the washings mixed with the sawdust.

If any NG is spilled, it should be cleaned up immediately. To do this, mop up first with a wet cloth which should then be put into the sawdust; then wash with one of the NG removers ("killers" or "destroyers") and finally wash the area with warm water and soap powder.

The following NG destroyer is commonly used at Picatinny Arsenal and elsewhere:
water 25ml, alcohol (95%) 69ml, acetone 20ml, sodium sulfide 7g. It takes 17ml of this soln to destroy 1 g of NG in 2 mins.

Refs for Glycerol Tests and Analyses:
1) Naoum, NG (1928), 25–40, 229
2) J.W. Lawrie, "Glycerol and Glycols", Reinhold, NY (1928) (ACS Monograph No 44)
5) L.W. Bosart & A.O. Snoddy, "Specific Gravity of Nitroglycerin", IEC 20, 1377 (1928)
6) Hercules Powder Co Manual G50, Revised 4/21/43
8) K. Namba, KogyoKakakkuKyokaishi 23, 76–7 (1963) & CA 63, 973S (1965) (Calculation of the heat of reaction in the nitration of glycerin) (The values are given in CA)
9) Kirk & Orthner 10, 627(1965)

Glycerol (or Glycerin) Acetates. See under Acetins and Derivatives in Vol 1 of Encycl, pp A31-L to A33-R.

Glycerol (or Glycerin) Acetate Dinitrate. See Dinitroacetin in Vol 1, p A33-L and as Glycerol Dinitrate Monoacetate in Blatt, OSRD 2014(1944)

Glycerol (or Glycerin)-α,α'-bis-[2,4-dinitrophenylether],
\((\text{O}_2\text{N})_2\text{C}_6\text{H}_4\text{C}_2\text{H}_5\text{CH(OH)}\cdot\text{CH}_2\cdot\text{O}\cdot\text{C}_6\text{H}_4\cdot(\text{NO}_2)_2\text{a}) \text{; mw 425/09, N 13.18%; yel crys (benz-eth), mp 790; sol in alc & hot benz. Prepd by heating the silver salt of 2,4-dinitrophenol} \text{.} \)
with epichlorohydrin in alc.
Refs: 1) Beil 6, (126) 2) M. Brenans, Bull.
SocChFr [4] 13, 529 (1913)

Glycerol (or Glycerin) Chlorohydrin and Its
Nitrated Derivatives. See under Chloropropene-
diol and Derivatives in Vol 3, pp C265-L to
C267-L. The dinitrate is described in Blatt,
OSRD 2014 (1944) as Glycerol Monochlorohy-
drin Dinitrate or a-Dinitrochlorohydrin

Glycerol (or Glycerin) Diacetate and Its Nitrates.
See Diacetin and Ird Nitrates in Vol 1, p A33-L,
under Acetins and Derivatives

Glycerol (or Glycerin) Dichlorohydrin and Its
Nitrated Derivatives. See under Dichlorohydrin
and Derivatives in Vol 5, pp D121-L to D121-R
and in Blatt, OSRD 2014 (1944), as Glycerol
Dichlorohydrin Nitrate

Glycerol (or Glycerin)-a,β-diethylether-β-nitrate,
H₂C₆₂.Ο.CH₂₂.CH(ONONO₂).CH₂.Ο.C₆₂Η₅; mw 193.20,
N 7.25%; liquid, bp 169°(dec). Can be prep'd
by dropwise addition of the diether to mixed acid
at 0°.

It is an expl, which easily decomposes on
heating and does not seem to be suitable as
military expl (Ref 3)
Refs: 1) Beil 1, 515 2) E. Paterno & T.
Benelli, Bass 39 (II), 312 (1909) & CA 4, 381
(1910) 3) A.H. Blatt & F.C. Whitmore, OSRD
1085 (1942)

Glycerol (or Glycerin) Dinitrate. See under
Glycerol (or Glycerin) Nitrates and in Blatt,
OSRD 2014 (1944)

Glycerol-α-(1,3-dinitrophenylether),
(Ο₅Ν).C₆H₅.Ο.CH₂₂.CH(ΟΗ).CH₂.ΟΗ; mw 258.19,
N 10.95%; crystals, mp 85°; sol in w, alc, eth.
& acet. Prep'd from glycine, 4-chloro-1,3-
dinitrobenzene and KOH
Refs: 1) Beil 6, 255 & (1879) 2) C. Will-
gemdl, Ber 12, 766 (1879)

Glycerol-α-[2,4-dinitrophenylether] Dinitrate
(Dinitryl) or 1-(2,4-Dinitrophenoxy)-2,3-propane
Dinitrate,
(O₂(NO)CH₂₂.CH(ONO₂).CH₂.Ο.C₆₂Η₅(NO₂)₂; mw
348.19, N 16.1%, OB to CO₂ -50.5%; crysts,
mp 124°. This expl compd originally prep'd in
1909 in Germany (Ref 2) was also prep'd (accdg
to G.D. Clift) during WWII by Hercules Powder
Co from ortho- or para-nitrophenoxide and gly-
ceryl monochlorohydrin, followed by nitration;
it was also prep'd by nitration of glycerol-α-
phenyl ether. It proved to be an expl slightly
more powerful than PA and of nearly the same
sensitivity to impact. Can be initiated by No 6 cap
Refs: 1) Beil, not found 2) Coll, Zentral-
stelle für wissensch-tech Untersuchungen in
Neubabelsberg, Annual Rept (1909) 3) Blatt,
OSRD 2014 (1944) 4) G.D. Clift, Private
Communication (1960)

Glycerol-α,α'-dipicrylether-β-nitrate,
O₃N.O.CH(CH₃.O.C₆₂Η₂.N₃O₆)₂; mw 559.28, N
17.53%, OB to CO₂ -59.1%; Ir-ey solid, mp
158-62°(dec). Prep'd by mixed acid nitration
of glycerol-α,α-diphenylether. It is expl
Refs: 1) Beil 6, (141) 2) Dinamite Nobel,
SA, GerP 294813 (1916)

Glycerol (or Glycerin) Ethers, Nitrates of. E.
Paterno & T. Benelli, Gazz 39, 312 (1909) &
J SocChemInd 28, 1168 (1909); CA 4, 381 (1910),
prep'd the nitroderivatives of α-dimethyl and
alpha-diethylethers of glycerol by the action of
methyl- or ethyl-alcoholics solns of KOH on
epichlorohydrin and then nitrating the resulting
ethers by nitric-sulfuric acid mixture. They
obtained:
Dimethyl Glycerol Ether Nitrates,
(H₂C₆₂.O)CH₂₂.CH(ONO₂).CH₂(OCH₃); colorless
liquid, mp about -15°, bp +180°; sol in common
organic solvents; uses ready without expln
when ignited by flame
Diethyl Glycerol Ether Nitrates,
(H₂C₆₂.O)CH₂₂.CH(ONO₂).CH₂(OCH₂); colorless
liquid, mp below -75°, bp 168-70°. Both the
dimethyl and diethylnitrates compds readily
gelatinize NC and may also serve as antifeuze
addns to Dynamites. When added to NG, they diminish its power without diminishing its sensitivity appreciably.

**Glycerol Formal**, \( \text{HO-CH}_{2}\text{CH}_{2}\text{O-CH}_{2}\text{O-CH}_{2} \text{ and HO-CH}_{2}\text{CH}_{2}\text{O-CH}_{2}\text{O-CH}_{2} \text{, mw 104-10. Exists in two isomeric forms, both prepd in 1896 (Ref 2) and again in 1930 (Ref 3) by heating formaldehyde and glycerol in presence of HCl. It is a liquid which boils at 195° and proved to be a good solvent for cellulose esters, resins, etc (See also Ref 4).}


**Glycerol Formate (or Formiate) Dinitrate.** See Formylglycerol Dinitrate or Formimin Dinitrate, under Formylglycerol or Formamin and Derivatives in this Vol, p F173-R

**Glycerol-Glucose and Glycerol-Lactose Nitrates.** See Glucose-Glycerol and Lactose-Glycerol Nitrates

**Glycerol-glycol-ether Trinitrate**, \( (\text{O}_2\text{N})\text{CH}_{2}\text{CH(ONO}_2\text{)}\text{CH}_2\text{O.CH}_2\text{CH}_2\text{(ONO}_2\text{)}\text{); mw 271.14, N 15.50%, OB to CO}_2\text{ -26.6%; liq, sp gr 1.481, nD 1.4685 at 20°, heat of combustion at const vol 2.4Kcal/gm. Prep'd by nitration of the parent triol ether at 20° with mixed acid or 99% nitric. Functions as a gelatinizer (presumably for NC, Ref 4). Much less volatile at 80° than NG, lying between EDNA and ethylcellulose nitrate (Ref 3).}


**Glycerol-\(\alpha,\alpha'\)-hexanitrodiphenyl Ether-\(\beta\)-nitrate; Glycerin-\(\alpha,\alpha'\)-dipicrylether-\(\beta\)-nitrate or Nitro-butyricerol Dipicrate, (\(\text{O}_2\text{N})\text{C}_2\text{H}_2\text{O.CH}_2\text{CH(ONO}_2\text{)}\text{CH}_2\text{O.C}_6\text{H}_2\text{(ONO}_2\text{); mw 559.30, N 17.57%, OB to CO}_2\text{ -50%; it yel solid, mp 158-62°; bp - dec at 174° c. Can be prep'd by nitratng glycerol-\(\alpha,\alpha\)-diphenylether with mixed acid. It is an expd nearly as powerful as PA, as detd by the Trauzl Block Test and is very insensitive to impact, as detd by Kast Apparatus Reifs: 1) Beil 6, (141) 2) Coll, Zentralstelle für wissensch-techn Untersuchungen in Neu-babelsberg, Annual Report (1909) 3) Dynamit. AG, BritP 24352 & CA 24, 352(1916) 4) Blatt, OSMR 2014(1944)
Glycerol Monochlorohydrid Dinitrate. See in Vol 3 of Encycl, pp C265-R & C266, under Chloropropanediol and Derivatives and in Blatt, OSRD 2014(1944)

Glycerol Mono-α-[2,4-dinitrophenyl]-ether. See Glycerol-α-(2,4-dinitrophenylether) in this Vol

Glycerol Monoglycolate Trinitrate, (O₂NO).CH₃.CH(OONO₂).CH₂.O(COCH₂.OONO₂); mw 285.13, N 14.74%, OB to CO₂ = 14.0%; oily liquid with a viscosity greater than NG. It was prepared by the DuPont Co by nitration glycerol monoglycolate. It is an exp less sensitive to impact than NG and possessing satisfactory thermal stability; less volatile than NG
Refs: 1) Beil, not found 2) Blatt, OSRD 2014(1944)

Glycerol (or Glycerin) Monolactate Trinitrate or Glycerol Lactate Trinitrate (GLTN), (O₂NO).CH₂.CH(OONO₂).CH₂.O.C(O).CH(OONO₂); CH₃
mw 299.16, N 14.04%, OB to CO₂ = 29.4%; oily liquid, slightly more viscous and less volatile than NG; sp gr 1.47, nD 1.464 at 25°; nearly insol in w; miscible with eth, 2/1-eth/alc & acetone

Was first prepd in 1931 by nitrating glycerol lactate with mixed acid (Ref 2). The prep of glycerol monolactate by heating glycerol with equimolecular proportion of a lactic acid ester of an alcohol boiling below 100°(such as ethyl lactate) was patented in 1936 (Ref 3). Blatt (Ref 4) described heating of glycerol with lactic acid for 30 hrs at 110°, followed by nitration. Accdg to AMCP 706-177 (Ref 7), glycerol monolactate was prepd by heating a glycerol-lactic acid mixt (contg 4% excess lactic acid) at 116° for 112 hours with dry air bubbling thru the liquid. The product which contd 0.67% free acid was carefully mixed with six parts of 40/60-HNO₃/H₂SO₄ maintained at 20°, stirred for 1 hr cooled to 5°, and poured on ice. It was extracted with ether, water-washed, adjusted to pH 7 by shaking with a Na bicarbonate soln, and again water-washed three times. It was then dried with Ca chloride, filtered and freed of ether by bubbling with air until minimal loss of wt was obtd. The product had a nitrate-nitrogen content of 13.43% (theory 13.04%). Another batch, prep from glycerol lactate contg 0.5% excess glycerol had a nitrate-nitrogen content of 14.30%, corresponding to a mixt contg 5.5% NG. It is not considered practicable to prepare pure GLTN.

The following are properties of GLTN:
Brisance by Sand Test. 13.1g sand crushed by 0.4g sample (vs 48.0g for TNT)
Explosion Temperature. 223° in 5 secs (vs 475° for TNT)
Friction Pendulum Test. Unaffected by fiber or steel shoe (same as for TNT)
Heat of Combustion. 2407cal/g (vs 3620cal/g for TNT)
Heat Test at 100°. 2.5% bss in 48 hrs, 1.8% in 2nd 48 hrs and no exptn in 100 hrs (vs 0.2, 0.2 and no exptn in 100 hrs for TNT)
Hydrolysis. 0.021% acid after 10 days at 22° or 0.014% after 5 days at 60°
Impact Sensitivity. BurMinesApp, 2kg wt, 42cm (vs 95-100 for TNT)
Impact Sensitivity. PicArsn App, 1 lb wt - 15 inches for 20mg sample (same as for TNT)
Power by Ballistic Mortar. 114% of TNT (Ref 6)
Vacuum Stability Test at 100°. 5.9cc gas evolved from 5g sample in 40 hrs (vs 0.10cc from TNT)

Macy & Saffitz examined at PicArsn (Ref 5) GLTN as possible expl plasticizer for NC and found it acceptable from most standpoints, but a less effective gelatinizer than NG

Glycerol (or Glycerin)-α-monomethylether Dinitrate,
GLYCEROL (OR GLYCERIN) NITRATES AND DERIVATIVES

1-Nitroglycerol, a-Glycerol Nitrate, HO.CH₂.CH(ONO₂).CH₂.ONO₂; mw 187.09, N 10.22%, OB to CO₂ ~52.5% (plates from w), mp 54°, bp 155~60°; sol in w & alc, sol in eth. Prepd by nitratation of glycerol. Prior to the publication of Ref 4, it was thought to be the 2, or β, nitrate. It is not expl.

2-Nitroglycerol, β-Glycerol Nitrate, HO.CH₂.CH(ONO₂).CH₂.OH; mw 187.09, N 10.22%, OB to CO₂ ~52.5%; colorless prisms (from w, alc or eth), sp gr 1.40, mp 58~9°, bp 155~60°; sol in w & alc; dif sol in eth. Prepd by treating 2,3-epoxy-1-propanol with dil nitric acid. Prior to the publication of Ref 4 it was thought to be the 1, or α, nitrate. It is not expl.

Ref for Glycerol Mononitrites:

1,2-Dinitroglycerol, a,β-Glycerol Dinitrate, HO.CH(ONO₂).CH₂.ONO₂; mw 182.09, N 15.38%, OB to CO₂ ~17.6%; oil, bp 146~8° at 15mm Hg, does not solidify on cooling; sol in w, alc, eth. Prepd by mixed acid nitration of glycerol below 20°.

1,3-Dinitroglycerol or a,a'-Glyceroldinitrate, O₂N.O.CH₂.CH₂.OH; CH₂.ONO₂; mw 182.09, N 15.38%, OB to CO₂ ~17.6%; crysts, mp 25° (with 1/3 H₂O); sol in w, alc & eth; in the anhydrous state it is an oil, fr p ~40°, sp gr 1.47 at 15°, bp 146~8° at 15mm Hg (slight dec); denatures on heating. Can be prepd by mixed acid nitration of glycerol below 20°.

Commercial Glycerol Dinitrate, liq, sp gr 1.517 at 20°, bp 146° at 15mm (slight dec); sol in w, alc, eth, chlf & NG; hygroscopic. Prepd by incomplete nitration of glycerol using straight nitric acid (sp gr 1.5) in a ratio of 3~4p to 1p glycerol, giving an isomeric mixture (Ref 5, p 164, by A. Mikolaiczak). About 20% lower yield results by nitratation with 5p of mixed acid contg nitric acid 23% & sulfviric acid 68% at or below 20° (Ref 4). It is an expl 81~83% as powerful as NG and about 70% as brisant by the lead block compression method. It is slightly less sensitive to impact than NG and slightly more stable to heat.

NC gelatinized with it is sticky, hygroscopic, and less elastic compared with NG gelling. The DNG explodes according to the equation:
\[ \text{C}_6\text{H}_5\text{(OH)(ONO}_2\text{)}_2 \rightarrow 2\text{CO}_2 + \text{CO} + 2\text{H}_2\text{O} + \text{N}_2 + \text{H}_2\text{O} \]

developing a heat of expl of 1304.4 cal/g at C, and 1201 cal/g with H2O (v) (Ref 5, p 169). The heat of formation is 116.7 kcal/mole.

When heated slowly DNG can be evaporated without expl or deflagration, but when heated rapidly in the open it deflagrates with a slight noise. For this reason expls containing DNG and no NG are much less sensitive to heat Uses: DNG has been used as an antifreeze in NG Dynamites. Advantage was taken of its lower mechanical sensitivity and much lower thermal sensitivity compared to NG in the prep of these dynamites manuf’d in France (Ref 3).

1) DNG 60, AN 35 & NC 5%
2) DNG 40, KNO3 51, curcuma (meal) 4.4, cellulose 4 & NC 0.6%
3) DNG 35, AN 38.4, Na oxalate 12, NH4Cl 9.4, TNT 2.5, cellulose 2 & NC 0.7%
4) DNG 58, KNO3 36, cellulose 4 & NC 2%

Ref:s on Glycerol Dinitrates:
1) Beil 1, 515, (272) & [591]
2) W. Will, Ber 41, 1110(1908)
3) M. Dauteucie, MP 14, 185(1906–07) & CA 3, 2053(1909)
4) Marshall, 1(1917), 238 & 2(1917), 704, 706
5) Naoiun, NG(1929), 161–70
6) G. Desseigne, MP 45, 103–114(1963) & CA 63, 5516(1965)(Prep of dinitrates and deriv of glycerol)

Glycerol Acid Dinitrate,
\[ \text{O}_2\text{NOC}_2\text{H}_2\text{CHO(NO}_2\text{)}_2\text{C}(\text{OH})_2\text{H} \]; mw 196.09,
N 14.28%, OB to CO2 0.05%; wh crystals (from benz or eth/lig), dec 117°C; sol in w, alc & eth. Prepd by treating 2,3-dihydroxypropanoic acid with mixed acid at ~12°C.

Ref:s: 1) Beil 3, 397
2) H. Duval, CR 137, 573(1903)

Glycerol Methyl Ether Dinitrate. See Glycerol (or Glycerine) d-monomethyl ether Dinitrate

Glycerol Trinitrate or Nitroglycerin (NG) (Nitroglycerine in Fr, Nitroglycerin in Ger, Nitroglycerina in Ital, Nitroglycerina in Japan, Nitroglycerina in Span, Nitroglycerina in Russ). See Vol 5, p D1593-L to D1594-L for many of the physical props normally found following a compound name

Additional Physical Properties. NG is, when pure, a clear, colorless, oily liquid having no odor and a sweet burning taste. Two cryst forms are known: a glassy, triclinic labile one with fr p of 2.15, mp of 2.8°C, heat of cryst of 5.2 cal/g, heat of conversion to the stable form of 28.6 cal/g; a dipyramidal rhombic stable one with fr p of 13.8, mp of 13.8°C, heat of cryst of 33.2 cal/g. The tendency to supercool results in a narrow range of reported fr p and mp values. NG has an apparent bp of 145°C, which is merely the temp at which non-explosion becomes vigorous enough to resemble boiling. Apparently some decr occurs even during high vacuum distillation, but some reported values are 125°C (2mm Hg) and 180°C(50mm Hg). NG is slightly volatile with steam, requiring one liter of steam distillate to carry over 5ml of NG. The vapor pressure of NG is (°C, mm Hg): 15, 0.00130; 25, 0.00177; 35, 0.0045; 45, 0.01294; 55, 0.03587 (decomp begins at 50–60°C). Relative viscosity of NG (time in sec to run out a 10-ml pipet at 20°C) is 15, compared with 6 for water and 540 for glycerol. The solubilities of NG are: 1.8g per liter of w (20°C) & 2.5g per liter (50°C); 37.5g per 100g abs alc (0°C) & 54g per 100g abs alc (20°C); 40g per 100g 96% alc (20°C); 1.25g per 100ml CS2 (RT) – this low sol in CS2 is taken advantage of in extracting other expl ingredients from NG mixts; 2ml per 100ml CCl4; 20p per 100p trichloroethylene; 12p per 100p Ge (20°C) & 20p per 100p Ge (80°C); Solubilities of interest in NG are: 35g DNT per 100g NG (20°C); 30g TNT per 100g NG (20°C). NG and NGC are misc in all proportions and form two eutectics: a) 29% stable NG/71% NGC melting at ~29°C; b) 39% labile NG/61% NGC melting at ~33°C (Ref 14b). Lewis (Ref 14a) used published data on the temp dependence of density, surface tension and vapor pressure to calculate values for the critical constants of NG: Tc 720K, Pc 35.2 atm. He gives for the surface tension at any temp T(°K): γ(dyne/cm) = 94.58(T-720)/720.
Chemical Properties. NG reacts chemically as a nitrate ester, saponifiable to glycerol by alkali (preferably with peroxide present), and hydrolyzed by nitric acid to glycerol. In general, side products tend to be produced resulting from cleavage of the C-C bonds and oxidation of the alcohol functions.

Explosive Properties of NG. See also Vol 5, p D1593-R and D1594-L. In general, bulk NG is difficult to ignite by flame or heat, the ease of ignition improving as the NG layer becomes thinner; NG may expl instead of igniting if large quantities are subjected to localized, sudden heating. When frozen, NG is rather insensitive to shock, and in the liquid form becomes increasingly sensitive as its temp increases. However, NG is most shock sensitive when crystals are in contact with liq. Other expl props are:

Brisance by Hess Pb Block Test (Ref 8a). The stable crystal form was shown to have much greater brisance, and to have higher sensitivity than the labile crystal or liq forms.

Critical Diameter. A range from 3.9 mm at -20° to 1.1 mm at 70° is reported by Belyaev & Kurbangalina (Ref 15a).

Detonation Velocity. In 22 mm ID glass tubes (26 mm OD) with 7000 m/s PA fuse, deton vel of 9150 m/s, 0 m/s, 1165 m/s were obt for the stabile, labile, and liq forms, resp. Use of a 20 g Tetryl booster gave 9100 m/s for the labile form, while use of 10-15 g of the stabile form as a booster gave 8750 m/s for the liq form.

Electrical Sensitivity. At 50-60° NG liq or sand in filter paper does not ignite or expl from a 13 kV spark from an 8 μF capacitor (Ref 8b).

Gap Sensitivity. Blends of NG 15 and inert salt 85% (the latter sifted first thru 20 mesh/sq cm screen) were packed in two identical 30-32mm diam paper tubes, and placed end-to-end on dry sand a definite distance apart. Detonation of one tube resulted in detonation of the other at maximum gaps (in cm) for these salts of: NH₄Cl 25, NaCl 11, NaHCO₃ 10. Diammonium sulfate or carbonate, chalk or talc did not transmit the detonation even at zero gap. The particle size of the salts was of some importance, eg, for NaCl the optimum size was 0.10-0.12 mm in greatest dimension (Ref 10b).

Impact Sensitivity. Values determined by the drop weight method have the usual dependence on the instrument used, also having great dependence on the area of the impacted NG, the smoothness of the two surfaces involved, and the aeration of the NG. A force of at least 1000 g cm was found necessary when using a 5-cm diam weight, but a greater figure was found with a 2.5-cm diam. Even the slightest dents in the anvil will greatly increase the sensitivity of this test. Detonation is attributed to thermal ignition from compressed gas bubbles (the degree of compression being higher in a dent than in the body of the NG) (Refs 10a & 11a).

Power by Trauzl Test. Cavities of 390, 560 and 518 cc were obt for the stabile, labile and liq forms, resp (Ref 8a).

Temperature of Detonation. The value 4800°K is given for the conditions of NG = 3CO₂ + 2.5 NG = 3CO₂ + 2.5H₂O(g) + 1.5Sn₂ + 0.5 O₂ and a resultant pressure of 10000 atm, or 1100°K at 1 atm (Ref 16).

Historical. NG was first prep by Ascanio Sobrero in 1846 in Italy by adding glycerol to MA (mixed acid, usually nitric-sulfuric) at 10°. An expl involving a very small amount discouraged him from further investigation. NG prep by him still exists, stored under w, and washed occasionally. Sobrero referred to the material as "piroglycerina". NG was, as a dil alc soln, used medicinally, going under the name "glonoin" (See also in Vol 5, p D1585-R, and D1584-L to D1586-R for pre- and non-Nobel expl uses for NG). In 1863 Alfred Nobel, along with his father and brothers set up a laboratory-plant to make and study NG. Their initial methods involved "cold" and "warm" techniques. In the former, portions of glycerol were added to cooled MA in stone jugs with hand stirring and ice-w cooling, followed by drowning in cold w. The warm method was to simultaneously add streams of glycerol and cooled MA to a conical Pb vessel having perforations in the constriction which allowed the NG and spent acid to flow continuously into the ice-cooled drowning bath beneath. The capacity of the latter determined the size of the batch. (Certain "continuous" methods developed in the 1960's are based on this same idea.) Temp in the cone was maintained at 43-65°C by adjustment of the two streams. In either method, the NG was then dmnted from the tank, washed with warm w, then with warm carbonate soln until acid free. The cold method was given preference because of higher yield.
Once Nobel began licensing the construction of plants to make NG, they were generally built very close to the site of intended use as transportation of liq NG tended to generate loss of life and property; the shipping of frozen NG as practiced by Mowbray in the USA caused similar problems when the NG thawed prematurely or was not thawed properly. In what is called the Kopp Process equipment consisted of a stoneware jug for cooling and washing, a cast iron vessel for mixing, a Pb or porcelain measuring vessel for the glycerol, an iron stirring rod, and a glass funnel with attached rubber hose and stopcock for separating the oily NG from the wash water and dropping into glass flasks. The standard charge was 350g of glycerol slowly added to 2.8kg of stirred MA in an iron vessel kept in the icewater filled jug. The mix was then dumped into the icewater. The ag layer was decanted, the oil washed a few times, and the ag layer decanted again. The wet oil was moved to the funnel for final separation from the water. Total time was 15–20 mins, yield 80–90% of current best. This method, adapted somewhat for the "assembly line" procedure, continued into the 1970's, even in large plants. In 1868 Mowbray in Massachusetts introduced compressed air agitation. This later lost favor in the USA to mechanical agitation, but was universally adopted elsewhere for decades.

The next development was the Boutmy-Faucher Process used in Fr until 1882 and for a long time in Eng. The novelty was to dispense with the need for extensive cooling by preblending the glycerol and sulfuric acid (most of the exothermicity in the making of NG comes from an initial formation of glycerol sulfate). The predissolution occurred in a w-cooled iron trough, with stirring to keep the temp below 40°. The soln was then poured into crocks to cool overnight. Then with cooling and air stirring the MA was added, and the mixture allowed to sit overnight because of very slow separation of the NG. The contents were then drained via a cock. Although yield was higher than in the Kopp Process when everything went right, it was often (enough to cause discontinuation of use) zero because the lengthy contact of spent acid and NG tended to cause expls. The quantities involved were nitric 280 & sulfuric 280 added to glycerol 100 & sulfuric 320 parts.

European equipment in the 1920's was still closed Pb cylinders with internal Pb cooling coils and compressed air stirrer, the mixture exiting from a large valve at the bottom. Operating temp was 20–30° or 12° if -10° brine was used for a slightly higher yield. The contemporary American equipment was all iron and steel cooled by -20° brine to give 2–3° mix temp with mechanical stirring.

No attempts to recover the spent acid were made until 1877. Artificial refrigeration in the form of 12° brine was developed over the period 1895–1905. The period 1904–1912 saw the introduction of materials to speed the NG separation time. Naum in 1904 was the first entrant in this field, patenting the use of liquid paraffins near the end of the glycerol addition, on the basis of 100cc for 250kg glycerol and 1600kg MA. In 1905 C. Reese patented the use of NaF; this turned out to require the presence of silicates, the desired effect being due to the evolution of SiF₄ gas. In practice NaF/glastr blend was added just before the reaction was over. The paraffin-NaF methods could be combined. Large scale recovery of the nitric acid involved flow of the spent acid down a packed column while superheated steam was rising. The carried-over nitric and nitrous acids were then cooled, or the nitrous first oxidized to nitric via an air stream.

**Laboratory Preparation.** See Titration Test, under GLYCEROL

**Batch Manufacture.** The raw materials are mixed acids (MA), mixtures of sulfuric and nitric acids, and "dynamite glycerol", the highest grade of commercial glycerol. The latter must be checked (first use of each new batch) for water content by the Karl Fischer Reagent method and for specific gravity by the pycometer method (1.263 at 15° is the required reading for 100% purity). The MA compn should be 52–55% sulfuric and 47–49% nitric. It should be prep’d well in advance of use to allow metallic sulfates to settle out (which otherwise might interfere with NG separation). Lower oxides of nitrogen should be minimal. An important factor in the compn of the MA is the Dehydrating Value of the Sulfuric Acid, known as DVS. This is the ratio of the sulfuric acid to water at the end of the reaction; the water amount will consist of that formed during the reaction and that present in
the raw materials. In practice the DVS is kept between 4.35–4.5 to assure good dehydrating ability throughout the reaction, which maintains the nitric acid at a concentration sufficient to insure completion of the reaction (see Vol 3, p D44).

Another factor to consider is the excess nitric required to drive the reversible reaction to completion. Theoretically 1 lb of glycerol needs 2.054 lbs of nitric, but in practice 2.3 lbs is used. The following are representative formulas used in the calculation of the MA compn (based on glycerol containing 1% w):

\[ A = \frac{N(0.59/R) + W + L(1.065/D)}{C(0.01225/D) + 0.01225} - 1 \]

where:  
- \( A \) = lbs of fuming sulfuric to be added to 100 lbs of premix  
- \( N \) = % actual nitric in premix  
- \( R \) = ratio of nitric to glycerol  
- \( W \) = % actual w in premix  
- \( L \) = % total NO\(_2\)  
- \( D \) = DVS  
- \( C \) = % SO\(_2\) in A

and

\[ A = \frac{N(0.59/R) + W - S/D}{C(0.01225/D) + 0.01225} - 1 \]

where \( S \) = % actual sulfuric in premix, and the other letters are the same as defined for the first formula.

Refer to Figure G18a (from Ref 14c) for a flow chart of a typical acid prep plant involving on site manuf of nitric, purchase of 65% oleum sulfuric, and recycling of spent acid; the figures are for MA for NG prep and would be different for NC, TNT, etc. The pre- or semi-mix consists of a blend of 97% nitric and 40% oleum sulfuric (contg 6% nitric as anti-freeze). Analysis of the pre-mix gives the values for the variables in the two formulas. Then A lbs of the 40% oleum is added to give the final MA blend.

Refer to Figure G19 (Ref 14) for a flow chart of a typical batch prep of NG (or EGDN or EGDN–NG). In the USA the reactor is of steel, equipped with steel cooling coils and mechanical agitation. A 6800 lb charge of MA is run into the reactor with -20° CaCl\(_2\)-brine-cooled coils and stirring. The glycerol is added in small stream while closely watching the temp for any tendency to rise. The temp is maintained at 2–3° by cutting off the glycerol as necessary; should this action fail to bring about the desired cooling immediately, the charge is drown in the water tank beneath the reactor. With adequate stirring the NG does not freeze to the coils as formed because its frp is lowered by the incorporation of the acids. Stirring is continued for a few mins after the 50–60 mins required to add the glycerol. Then the NG is allowed to separate completely. The lower layer of spent acid is drained off to be recycled or otherwise disposed of, and the NG is run into the neutralizer. An initial 40° w wash removes most of the acid. Then 2–3% sodium carbonate soln neutralizes the residual acid. Finally a concd soln of NaCl breaks any NG–w emulsion. The (tested) neutral NG is then transferred to storage or mix house (Dynamite, Smokeless Powder, etc).


Desensitization of NG. See Desensitizers and Desensitized Explosives, Vol 3, pp D88–R to D90–L.

FIG G18a  Acid-operation flow chart
Toxicity of NG. According to Sax (Ref 25), NG is classed as highly toxic (meaning death or permanent injury after very short exposure to a small quantity) after ingestion, inhalation, or skin absorption. Poisoning symptoms consist of headaches and reduced blood pressure, excitement, vertigo, fainting, respiratory rales, and cyanosis. Taken internally it causes death from respiratory paralysis. Under normal manuf conditions no symptoms are observed during the work week (after an initial reaction in most new workers in the form of severe headaches). Over the weekend or vacation periods the worker may have to take small doses of NG to prevent onset of the headaches. The threshold limit value (TLV) as determined by the American Conference of Governmental and Industrial Hygienists (ACGIH) is 0.2ppm or 2.0mg/cu m in air and is good for the atmosphere to be found in NG plants where a mixture of 60–80 EGDN and 40–20 NG is currently being manufd instead of straight NG. In the ACGIH publication (Ref 26) the same TLV is given, but it is also recommended that the value be only 0.02ppm when the exposure is intermittent rather than continuous, as there seems to be some evidence that the deaclimatization process is physiologically dangerous. Good ventilation is a must as the vapor pressure of NG at 20–25° corresponds to about 2ppm

Uses of NG. Aside from the expl uses discussed under Dynamite and Smokeless Powder (NG gelled with NC), the only extensive use for NG is as a depressor of blood pressure in the treatment of angina pectoris where it is in competition with other polyl nitrates. There is voluminous literature on the pros, cons, and wherefors of this subject


Glycerol Trinitrate, Analytical Procedures. NG, as well as many other noninitiating expls can be identified by making a series of tests, such as described in SndMethodsChemAnalysis (Ref 12a, p 1347), and comparing the results
with those given in Table 32-2 on p 1348. The tests are as indicated below:

Test 1. Place 0.05g of unknown expl in a 5-ml beaker, add 2-3ml of distd w, and stir for 5 min. Observe the color of the liquid. (No color is given by NG, EDNA, NGc, NGu, NC, AN, Ednatol, Ammonol, Ammonal, and BkPdt). Add a drop of Nessler’s reagent and note the color of any ppt formed. (No ppt is formed by NG, PA, NGc, NGu, NC, EDNA, Ednatol, BkPdt, and Pentolite)

Test 2: Place 0.05g of unknown material in an indenture of a wh porcelain spot test plate. Add 2-3 drops of a 65-68% soln of ethylene diamine, and stir. Note the color of the soln (not the solid). (NG produces no coloration, nor does NGc, NGu, EDNA, NC, and BkPdt)

Test 3: Same as Test 2, but add 2-3 drops of DPHA reagent (1g DPHA in 100ml concd sulfuric acid). Stir and observe the color after 1 min. (Deep blue is produced by NG, NGc, Ednatol, & Tetrytol; blue is produced by Tetryl, EDNA, NG, NC and BkPdt)

Test 4: Same as Test 2, but add an equal amt of cryst thymol and 3 drops of concd sulfuric acid. Stir and observe the color after 5 mins. (NG gives green color and so does Tetryl, NGu, AN, PETN, Tetrytol, Amnatol, Ammonal, Pentolite, and BkPdt)

All this can mean that, if the aq soln of unknown sample is colorless in Test 2, no ppt with Nessler’s reagent, no color with ethylene diamine in Test 2, deep blue color with DPHA in Test 3 and green color with thymol soln in Test 4, it could be NG

Munch et al reviewed in Ref 13 the variety of spot color tests for the nitrate radical which can be used for det of NG

Other methods for det of NG are described in Refs 1, 2, 3, 4, 7, 8, 10, 10a, 11, 14, 15 & 16

The stability of NG is normally checked by Abel Heat Test which is briefly described in Vol 1 of Encycl, p A2-L. The test conducted accdg to Spec MIL-N-246B is described below. Since the test is sensitive to the amt of w in NG, it is required to test each sample for moisture content

3.1 Nitroglycerol. There are two types of NG used in propellants: Type I is prep from Grade B glycerol and Type II from partially polymerized glycerol. Grade B glycerol shall comply with Federal Specification O-G-491. Partially polymerized glycerol shall contain 27 to 31% by wt of polymer glycerol, expressed as diglycerol

3.2 Moisture Content. 0.5% (max) when detd as specified in 4.3.1. When NG is used at the point of manuf in the production of propellant by the water-slurry method or by the water emulsion method, the moisture requirement shall not apply

3.3 Acidity or Alkalinity. The acidity as sulfuric acid or alkalinity as Na carbonate shall be 0.002% (max), when detd as in 4.3.2.

3.4.1 Nitrogen Content for Type I. 18.40% (min) when detd as in 4.3.3

3.4.2 Nitrogen Content for Type II. 17.90% (min) when detd as in 4.3.3

3.5 Stability. When subjected to 82°C heat test as described in 4.3.4, NG shall not change the color of the std KI-Starch paper in less than 10 mins

4.2 Inspection and Provision. See p 4 of Spec 4.2.3.1. Sampling. Using a rubber dipper, a sample of approx 2 oz shall be removed from each lot and transferred to a rubber bottle with a rubber stopper. The bottle shall be labeled to show source of manuf, plant, contract or purchase order, lot and number of pounds in the lot

After disposal of the NG from the rubber sample bottle, the bottle shall be cleansed thoroughly with acetone, flushed during about 3 mins under direct flow of tap w, rinsed with distd w and dried

4.3 Test Methods and Procedures:

4.3.1 Determination of Moisture in NG by Karl Fischer Reagent. Place a 5-10g sample of the NG into a tared narrow-necked stopperable flask and tare. Titrate directly with standardized Karl Fischer Reagent until a brown color remains for 30 sec, or use a potentiometric endpoint. Then,

$$\text{% Moisture} = \frac{100(KF)}{W}$$

K = ml of reagent used, F its factor (g of w per ml of reagent) and W = wt of NG sample in g

(More detailed description of Karl Fischer Method, including prep of the reagent, is given in Vol 5 of Encycl, pp D1622-L to D1628-L)


3. Requirements:
4.3.3. Determination of Nitrogen in NG

4.3.3.1. Standardization of Nitrometer. Standardization of the DuPont 5-part form of Lunge nitrometer shall be made by Method 209.3 of Standard MIL-STD-286. A detailed description of the method as was conducted during WWII at Keystone Ordnance Works, Meadville, Pa. is given in Vol 1 of Encycl (Ref 10a, pp A374-R to A376-L). The apparatus, illustrated on p A374-L, shall be used while following the description of standardization and of the procedure 4.3.3.3.

4.3.3.2. Drying of Filter Paper. Whatman No 42 or equivalent filter paper shall be transferred to a glass weighing dish equipped with a glass cover. The uncovered dish and contents shall be heated at 100°F for 2 hrs, the dish covered, and cooled in a desiccator.

4.3.3.3. Procedure with Nitrometer. Quickly place at least four dried filter papers in a dry conical funnel, then immediately add about 10g of sample NG, apply suction and collect the NG in a dry flask. Place 0.70–0.75g of the filtered NG into a tared 25-mL beaker and retare. Add 5mL of glacial acetic acid and stir with a small glass rod to dissolve the NG. Using the rod to avoid spillage, transfer the soln quickly to the cup (a) of the generating (or reaction) bulb (E) of Fig reproduced here. Draw into the bulb without allowing air to enter. Rinse the beaker and rod with successive 5-mL portions of 25mL of 94.5±0.5% sulfuric acid, separately, placing each wash into the bulb cup (a), agitating with the rod, and then drawing into the bulb (E). Force out any air inadvertently admitted to the bulb and close the upper stopcock (c) when the last of the wash has been added. Leavin the lower stopcock (f) open, adjust the level of the Hg in the reservoir (F) to 13–15 inches below the level of the Hg in the bulb (E). At this point inspect the cock (c) to see if there is any leak into (E). Make sure that cock (F) is open.

Put on a full-view mask, wrap bulb (E) in several layers of cloth toweling and remove E from the rack. Gently shake the bulb, keeping the lower end fixed, until most of the NO has been generated. Then adjust the Hg reservoir (F) so that the Hg in the bulb drops almost to the lower shoulder, close the lower stopcock (f), and vigorously shake the bulb for 3 mins. Replace the bulb on the rack and let stand for 3 mins. Repeat the 3-min vigorous shaking and standing two more times. Care must be taken not to shake the bulb so vigorously that the acid is carried down thru (f) into the connecting rubber tubing (r).

Remove the towelling from (E) and raise it so that the Hg could flow thru (f) into (F), thus creating a vacuum in (E). When 1–2 inches of Hg (not of emulsion) is left in the bulb (E), close the stopcock (f).

With the cocks (c) & (f) tightly closed and held by the fingers, place (E) in a nearly horizontal position and shake vigorously for 2 mins.
By this time the mass must be a nearly homogeneous emulsion. Replace (E) on the rack and allow the emulsion to settle.

While waiting, slightly grease the outside of capillaries K1 & K2 and see that they are filled with Hg. Raise or lower the measuring tube (D) so that (K1) will be on the same level as (K3). Slip a piece of heavy rubber tubing (h) 7 inches over (K3) and push it all the way thru. Place the end of (K4) against (K1) and push the tubing (h) over the junction until both capillaries are equally covered.

Now lower Hg reservoir (A), raise reservoir (F), and by opening the cock (f), let the Hg enter bulb (E) from (F) with formation of some pressure. Open the cock (d) of (D) and examine for any leakage. Normally the Hg in capillary will move slightly due to the presence of rubber connections and traces of air.

If there is no leak, leave (d) open and, by manipulating carefully with (c), allow the NO gas to flow slowly from (E) to (D). Towards the end of transfer, partly close (c) to slow down the rate of flow and, just as soon as the acid starts to fill the capillaries, close (c). No acid shall enter (D) and no gas shall remain in the capillaries. Close (d), but leave (f) open.

Adjust the levels of Hg measuring (D) and compensating (C) tubes until they are about the same, with that in the latter tube near the standardization mark. Let stand 20 mins to permit temperature equilibration. Keep the Hg level in the compensating tube at the standardization mark and equalize the level in the measuring tube with the aid of a U-tube leveling device carefully colored with methyl red indicator. Then, \[ 2N = A/0.9983W \], where A is the reading of the Hg level on the measuring tube, W is the weight of NG used, and 0.9983 is a factor based upon the experimental data average moisture content of NG filtered as described.

4.3.4. Determination of Stability of NG. Filter a sample of the NG thru two layers of S&N No. 604 paper (or equiv.). Place 2ml of the filtered sample by pipet into each of three 5.5 x 0.5-inch test tubes in such a manner as to leave no NG on the sides. Stopper each tube tightly with a new cork, itself tightly attached to a glass rod, to the end of which in the tube is affixed a Pt holder with a 1 x 3/8-inch strip of standard KI-Starch indicator paper (attached by means of a forceps, not the fingers, and having a horizontal band in the upper half just wet thru with 50-50 (v-v) glycerol-distilled water. Similarly equip a clean, dry tube as a blank. Adjust a bath to 82.22°C, then submerge the four tubes to a depth of 2 inches and note the time of insertion. Against a white background lit by bright diffused daylight, observe the line demarking the bottom of the wet band from the dry paper (which line should be 3 inches above the NG, and an equivalent height above the bottom of the blank tube). To the nearest min note the elapsed time when any discoloration of the line in any of the NG tubes exceeds any discoloration of the line in the blank. Record this time as the value for the test, and do not average the values for three tubes.

Nitroglycerol, Tests Not Required by Spec MIL-N-2468.

Determination of Purity of NG by Redox Titration. The two equations representing this method are: \[ \text{NG} + 9\text{Fe(II)} + 9\text{H}^+ = \text{G} + 9\text{Fe(III)} + 3\text{NO} + 3\text{H}_2\text{O} \], and \[ \text{Ti(III)} + \text{Fe(III)} + \text{Ti(IV)} + \text{Fe(II)} \]. Excess ferrous ion in hydrochloric acid solution is used to reduce the NG to glycerol (G) and nitric oxide. Thiocyanate indicator denotes the presence of ferric ion during a titration of the latter with standard titanous ion, the blood-red color disappearing with the last of the ferric species. Air must be rigorously excluded from the system because of the ease of oxidation of Ti(III), and carbon dioxide is generally used because of its heavier than air feature. For the indicator dissolve 20g reagent grade ammonium thiocyanate in 100cc distilled water, and filter if necessary. At the proper time transfer 5cc of this with a pipet whose tip has been removed for fast delivery. For the ferrous soln dilute 140g of ferrous chloride tetrahydrate and 50cc of concd HCl to 1 liter with w, using deaerated acid and w, and mixing with a current of carbon dioxide (about 0.7N). For the titanous soln dilute 150cc of a commercial 20% titranous chloride soln and 100cc concd HCl to 1 liter with w (about 0.2N); protect from air and store out of contact with light. Standardize the Ti(III) against Fe(II) (prepd by oxidizing standard ferrous ammonium sulfate (solid) with KClO₃, destiming excess chloride by evaporating to dryness: \[ 6\text{Fe(II)} + \text{KClO}_3 + 6\text{HCl} = 6\text{Fe(III)} + \text{KCl} + 3\text{H}_2\text{O} \] and \[ \text{KClO}_3 + 6\text{HCl} = \text{KCl} + 3\text{H}_2\text{O} + 3\text{Cl}_2 \]. Place about 2g NG in a tared beaker and retar. Dissolve in carbon dioxide-free HAc, and transfer
quantitatively to a 250-cc volumetric, and dilute to the mark with HAc, mixing well and avoiding any temprature change before use. Replace the air in a 300-cc Florence flask (equipped with a side arm for carbon dioxide) for 5 mins. Place a 25-cc portion of the NG-HAc soln in the flask followed by 15 cc of the Fe(II) soln, and then 25 cc of 15% (w/w) HCl, plus a few boiling chips. Connect to a reflux condenser and boil gently for 5 mins on a hot plate. The color will change from yellow to dark green to reddish brown. Increase the flow of carbon dioxide and immerse the flask in a large beaker of cold water, lightly blocking the top of the condenser until all vapors have condensed. Once cooled to RT, remove the condenser, insert a rubber stopper with a piece of glass tubing, and titrate with the Ti(III) — the carbon dioxide exiting thru the annular space between the buret tip and the tubing. As soon as the reddish color disappears, add the 5 cc of indicator and continue the titration until the red color disappears. Then, % NG = 2.523VN/0.1W, where V is the vol of Ti(III) corrected for a blank, N is the normality of the Ti(III), and W is the weight of the NG sample. Variations of this redox titration may be found in Refs 3, 4 & 8

Determination of Purity of NG by the Dewarda Method. This method involves the saponification of NG to glycerol and nitrate ion. The latter is then reduced with Dewarda’s alloy, a mixture of Al, Zn and Cu. The resultant ammonia is then distilled and titrated (Refs 2, 5, 10 & 17)

Determination of NG by Gas Liquid Chromatography. This technique is useful for measuring NG or other polyal nitrates present in air. Bubble a 1-liter sample thru two 10-ml containers of air, then inject some of the air soln onto a siliconized Chromosorb-P column coated with 10% Igepal CO-880. Run the analysis at 160° under nitrogen carrier to detect a min of 2 mg (Ref 14)

Determination of Composition of Mixed Acid. This analysis consists of titration of a sample for total acid, heating another sample to drive off the nitric acid and titrating the remaining sulfuric, and titrating a third sample with permanganate to determine the nitrosylsulfuric acid content. The latter is subtracted from the values for the nitric and sulfuric, the three corrected values added, and the (positive) difference from 100 taken to be the amount of w (See Ref 16 for details)

Refs on Analysis of NG: 1) Marshall 2(1917), pp 739–40 (Estimation of small quantities by reaction with phenol disulfonic acid to form PA and colorimetric measurement against K nitrate standards)

**Glycerol Trinitrate** (Glycerin trinitrate, in Ger), ONOCH(CH₂ONO₂)₃; mw 179.06, N 23.46%, OB to CO₂ –22.3%; yel liq (sl impure), sp gr 1.291 at 10/15.5°C; bp 130°C (sl dec); sol in eth, chl & benz; immisc with w; dec in air, w & abs alc. Prep by treating cold glycerol with N₂O₅.

**Nitroglycerol Shell** was invented by Fannon-Winslow about 1885. It contained two glass jars, one holding glycerol 1p and conc sulfuric acid 1p; the other nitric acid 2p and sulfuric 1p. A time fuze exploded a small charge of BKPr which broke the bottles, mixing the contents and producing NG. The impact of the shell exploded the NG causing the shell to burst.

Note: More successful than NG shells were shells contg NG gelatinized with 7–10% of CC (Collodion Cotton) which was added about 4% camphor (Ref 2, p D1610-L). Other types were loaded with Dynamite. They were propelled by compressed air from special pneumatic cannons. Accdg to Ref 1, p 934, the first of such shells was built in 1883 by Mefford of Ohio (See also Ref 2, p D1610-L). Accdg to Pérez Ara (1945), pp 333–34, Americans used large caliber pneumatic cannons in their coastal defenses and during Spanish-American War for bombarding Havana (See Ref 2, p D1610-R)

**Glycerolpentaoxyrhthritol Ether Pentanitrate**, O₂N₂O₂CH₂CH(NO₂)₂CH₂O₂C(CH₂ONO₂)₃; mw 435.21, N 16.09%, OB to CO₂ –23.9%; crysts, mp 54.5–55°C; sp gr 1.57 at 20/20°C; αD 1.531 and 1.520 at 31°C. No prep is given in Ref 2; presumably a mixed acid nitration at 0°C was performed on the (freshly made) parent.

**Glycerol-Peroxide Explosive** consisting of glycerol, w & hydrogen peroxide in the ratio within the triangle defined on a triangular graph by the corners: glycerol 5, w 10 & peroxide 85%; glycerol 15, w 52 & peroxide 33%; and glycerol 65, w 0 & peroxide 35%. Such comps are insensitive to mechanical shock, including rifle bullet, but are detonated by a blasting cap (Ref: E.S. Stanley & H.O. Kauffmann, USP 2452074 (1948) & CA 43, 1190 (1949)

**Glycerol Substitutes.** During WWII, the Germans developed several processes for preparing either glycerol or comps with similar propeties. The so-called Oppau Process of IGFarbenindustrie AG involving propylene chlorination and hydrogenation produced pure glycerol, while other processes gave mixes of glycerol with other substrates.

One such mixture was Glycerogen (qv)

**Glycerol-Sugar Nitrates**, including Nitrohydrodene. As sugar (saccharose C₁₂H₂₂O₁₁) is less expensive and more abundant, especially during a war, its nitration has been attempted. The resulting Nitratosugar (NSu), usually Heptanitrate, C₁₂H₁₆O₄(NO₂)₇, proved to be a very powerful expl., but very unstable because of the presence of impurities. Better results were obt
by nitrating 20–25% sugar soln in glycerol. The resulting exps were nearly as powerful as straight NG, but less stable. In order to increase their stabilities (especially at ca 50°C and above), 0.1–0.2% of DPhA was added (Refs 1, 2 & 3).

The idea of prep by such mixts originated with Björkman who in 1880 nitrated (in Sweden) a soln of glucose 25 parts in glycerol 76%. Then in 1911 an Engl P 17221 was issued to Cocking & Kynoch Ltd protecting a process of nitrating any mixt of glycerol and sugars, and finally a USP 1140487 was issued in 1915. Before this, however, the DuPont Co started to nitrate a soln of 20 parts of sugar in 80% of glycerol and named it Nitroglycerin. Accord to Symes (See translator’s footnote 58 in Ref 1, p 251), the ordinary table grade of refined sugar was used in the US, but a small quantity of refined glucose was added to prevent crystallizing NSU when shipped during cold weather.

Description of nitration process and some properties of NG–NSU mixts are given by Naoum (Ref 1); Davis (Ref 2) lists the same props as Naoum. If the expl strength of NG by Trauzl Test is 550cc, then the 80/20 Nitroglycerin gives 533 and a 75/25 mixe 514cc.

Accdg to Pérez Ara (Ref 4), Björkman gave the name of Glukodin to the mixt of NG 91.18 & NSU 8.82%, prepbd by nitrating a soln of saccharose in NG. Björkman also proposed Dynamites cong Glukodin, NC, Na nitrate & sugar. Daniel (1902), p 345 gave credit to Dittmar for using Glykodin in two expl mixtures.

Giuia (Ref 5) lists the following Dynamites cong NG–NSU:

a) NG 33.2, NSU 3.2, NC 24.3, Na nitrate 31.3 & sugar 8.0%; and
b) NG 30.2, NSU 4.0, NC 19.2, Na nitrate 37.8 & sugar 8.7%. They are similar to Dynamites listed in Pérez Ara and Daniel.

In Germany, the scarcity of glycerol during WWI led to the use of NG–NSU mixts in mining expls, but this practice was discontinued in peace time because saving in NG did not amount to more than 10–12%, but the acid consumption was greater than in nitration of glycerol.

Glycerol (or Glyceryl) Trilactate, HO.CH₂.C(O).CH(CH₂.O.C(O).CH(OH).CH₃)₂; mw 308.29; liq, does not boil at 40° at 0.4mm liq; sol in w, alc & methanol. Prepbd by hydrogen reduction in the presence of Pd of the corresponding tri-o-benzyl compd, the benzyl having been added prior to the ester formation for protection. Apparently the compd is too unstable towards heat for bp determination (See Ref 3).


Glycerol (or Glyceryl) Trinitramine (NGX) or 1,2,3-Trinitroaminopropane. It will be described under Triaminopropane and Derivatives

Glycerol-a-[2,4,6-Trinitrophenylether] Dinontrate; 1-[2′,4′,6′-Trinitrophenyloxy]-propane-2,3-dinitrate, Trinitril or Dinitroglycerol Picate [Called in Colver (Ref 5) a-Trinitrophenol-dinitroglycerin], (O₂NO)CH₂.CH(ONO₂).CH₂.O.C₈H₄(NO₂)₃; mw 393.18, N 17.81%, OB to CO₂ −34.8%; crystals, mp 128.5°, begins to decom at 119–20°. Was first prepbd by Voswinkel (Ref 2) in 1893 by treating an alcoholic soln of PA salts with a chloro- or bromodinitrohydrid, followed by crystallization of the resulting product. Blatt (Ref 7) lists three methods of prepns.

It is an expl s more powerful than Tetryl with nearly the same sensitivity to friction but more sensitive to impact.

Following propeties are listed in Blatt (Ref 7) & ADL (Ref 8):

Impact by drop of 10kg wt. 7–10cm vs 23–24 for Tetryl; Initiation Sensitivity. Detonates by No 6 cap; Power by Trauzl Test. 128–130% PA or 147% TNT; Rate of Detonation 3200m/sec, loosely loaded in a Cu shell; Rifle Bullet Test. Same as for Tetryl; Stability. Explodes at 235° when heated at the rate of 5°/min; Surveillance (Storage) at 80°. Lost in 8 days 28% wt and developed acid reaction.
It is not as good an initiator for PA as is
Tetryl (Ref 7)
Lewis (Ref 6) proposed it as a component for
detonator and booster charges
Refs: 1) Beil, not found 2) A. Voswinkel, GerP 74293(1893) & SS 9, 194(1893)
3) Zentralstelle für wissenschaft-technische Untersuchungen
in Neubabelsberg, Annual Rept of 1909
4) Dynamit Nobel, BritP 24352 & CA 10, 1597 (1916) 5) Colver (1918), 699 6) H.A. Lewis,
USP 1560426 & CA 20, 112(1926) 7) Blatt, OSRD 2014(1944) 8) ADL, PureExp/Compds,
Part 1(1947), 124 & 148

Glycerol (or Glyceryl) Tripermanganate,
O₃MnOCH₂O₃MnO₃; mw 397.88, OB to CO₂
& MnO₂ <10.0%. There is no reference to this
compound in the open literature. The inventor,
Mr Emil Dvorsk, claimed that the compd may be
prepd by the reaction between silver permangana-
tate & trichlorohydrine. It was proposed as an
expln possibly suitable for military & commercial
uses. All attempts to prep this compd at Pica-
tinny Arsenal were unsuccessful (Ref 3)
Refs: 1) Beil, not found 2) CA, not found
3) O.E. Button, "Study of the Preparation and
Explosive Characteristics of Glyceryl Permanganate", PATR 124(1931)

Glycerol (or Glyceryl)-tris(Trinitrobutyrate),
(NO₂)₂C.CH₂.CH₂.O[OOC.CH₂.O.C.CH₂.
CH₂.O[OOC.CH₂.O]]; mw 707.35, N 17.82%, OB to
CO₂ <32.8%; crystals, mp 92–3°C. There is no
reference to this compd in the open literature.
Acdng to Ref 3 below, the material flashes on
a hot plate, and detonates with a hammer blow
Refs: 1) Beil, not found 2) CA, not found
3) USRubberCo Quarterly Prog Rept 19 (May–
Aug 1952), p 5 (Contract NOrd 10129)

Glyceronitro. Same as Fortis described in this
Vol, p F174-R to F175-L and in Daniel (1902),
304 & 355

Glyceronitrocellulose. See Glyceropyroxyline

Glyceropyroxyline. One of the Clarke's Propels-
nants, listed in Vol 3 of Encycl, p C327-L and
in Daniel (1902), p 355

Glyceryl or Propenyl. Trivalent radical:
H₃C.CH₂.CH₂−, derived from glycerol, which
may be called glyceryl hydroxide

Glyceryl Tripalmitate. See Tracelint on p A31-R
of Vol 1, under ACETINS

Glycide or Epoxy-1-propanol (γ-Oxypropyleneoxyd,
in Ger) (Glicidol, Epibydric Alcohol or Anhydride
of Glycerol), O.CH₂.CH₂.CH₂OH; mw 74.08, co-
less liq, sp gr 1.114 at 16/16°C; bp 62°C at
15mm and 166–67°C at 760mm (with sl decompm).
very sol in w & in alcl. sol in eth & benz; sl
sol in pet ether & xylene. Can be prep by treat-
ing glycrol α-monochlorohydrin with calcd amt
of K or Na ethylate (Ref 3)
Although glycide is supposed to be the
parent compd of Nitroglycerol, it is not used
for such purpose because the oxygen bond
breaks down on action of strong acids. On
the other hand, weak nitric does not break the
O bond, but transforms glycide into glycerol mono-
nitrate (Refs 2 & 4). For this reason Nitrogly-
side is prepd by an indirect method described
below
Refs: 1) Beil 17, 104, (50) & [104] 2) M.
Hanriot, AnnChimPhys(Paris) 5, 17, 118(1879)
3) J.U. Nef, Annalen 335, 232(1904) 4) Naoum,
NG (1928), 171 5) Vol 5 of Encycl, p E106-R
(Brief description as 2,3-Epoxy-1-propanol)

Glycide Nitrate or Nitroglyceride (Nitrate of Epiphy-
dric Alcohol), O.CH₂.CH₂.CH₂(OONO₂); mw
119.08, N 11.76%, OB to CO₂ >60.5%, color-
less mobile liq, very volatile at ord temp, sp gr
1.332 at 20°C/4, fr p – did not freeze at -20°C;
bp 94°C at 20mm or 174–75°C at 760mm (with
partial decompm), detonates at 195–200°C(Ref 4);
sol in w (5% at 20°C); miscible with alc, eth,
aconm, etc acet & NG; decomps by heat.
Reacts explosively on contact with concd sulfuric
acid. Reacts with concd nitric acid with great evoln of heat and the formation of NG and Glycero Dinitrate

Can be prepd by shaking glycerol dinitrate (both alpha and beta isomers) at RT with 30%aq soln of Na or K hydroxide as was done by Naoum in 1907 (Refs 3 & 4). The Nitroglyceride deposited as a clear oil, was isolated, washed with w and dried in a desiccator. The yield was practically theoretical.

Nitroglyceride is a HE, very brisant (72% that of NG), about 52% as powerful as NG (compared to 36% for mononitroglycerol, whose anhydride it is), much less sensitive than NG: 10–20 cm vs 2 cm for NG with 2 kg wt. It is more sensitive to initiation by an ordinary Blasting Cap than NG, probably (in the opinion of Naoum) due to the lower viscosity of Nitroglyceride.

Recommended as a good plasticizer for NC (Ref 5)

Glycercol. See Aminoacetic or Aminoethanoic Acid in Vol 1 of Encycl, p A178-L

Glycine see Aminoacetic Acid in Vol 1 of Encycl, p A178-L

Glycine Nitrate. See Aminoacetic Acid Nitrate in Vol 1, p A178-L

Glycine, Nitro. See Nitroaminoacetic Acid or Nitroglycerine in Vol 1, p A178-R

Glycinonitrile, N-(4,6-diamino-s-triazin-2-yl), C₄H₇N₂; mw 165.15, N 59.39%; crystals (+2w), mp 220–257; sol in w, alc & dil acids; insol in hydrocarbons. Prepd from one mole of the 4,6-dichloro-compd and five moles of concd ammonia. 
Ref's: 1) Beil, not found 2) I. Hechenbleikner, USP 2476546 (1949) & CA 44, 4518 (1950)

Glycocol. See Aminoacetic Acid in Vol 1 of Encycl, p A178-L

Glycyramidine or Glycolylguanidine,
\[
\text{HN:C}<\text{NH-CH}_2\text{CO}_2\text{H} \quad \text{mw 99.09, N 42.41%; colorless crystals, mp - brown at 220°C; v sl sol in water; insol in alc & eth}.
\]

Can be prepd by dehydration of glycocyanine and by other methods. Forms numerous crystal salts (Ref 1) with metals & org compds
Ref's: 1) Beil 24, 244, (287) & [127] 2) Hackb's Dict (1944), 383-L

NOTE: No azido or nitrate derivs were found in Beil

Glycocamerine or Guanylglycine,
\[
\text{HN:C(NH}_3)_2,\text{NH-CH}_2\text{CO}_2\text{H; mw 117.11, N 35.88%; colorless ndls (w), mp 270–80°C; sol in w; v sl sol in alc or eth}.
\]

Can be prepd from cyanamide & glycine. Gives on dehydration glycoxyamide

NOTE: No azido or nitrate derivs were found in Beil

GLYCOLS (Gc's) AND DERIVATIVES
(Diols or Dihydric Alcoholx)

Glycols are alcoholcs of the aliphatic series that have two hydroxyl (–OH) groups attached to separate carbon atoms. They may be subdivided into (Ref 2):

- Diprimary – contg two –CH₂OH groups
- Dissecondary – ” ” CH₂OH ”
- Ditertiary – ” ” C₂OH ”
- Primary-secondary – ” one – CH₂OH and ” CH₂OH groups
- Primary-tertiary – ” ” – CH₂OH and ” C₂OH groups
- Secondary-tertiary – ” ” – CH₂OH and ” C₂OH groups

or they may be subdivided accdg to the number of carbon atoms they contain, such as C₂ glycols, C₃ glycols, C₄ glycols etc (Ref 3). Accdg to the Geneva Nomenclature, the C₂ glycol is called "ethanediol", the C₃ "propanediol" etc, but in more common use are the names ethyleneglycol,
propyleneglycol etc. For polymerized glycols, known in general as polyglycols, the names di-
ethyleneglycol, triethyleneglycol, or polyethyleneglycol are used for derivatives of ethyleneglycol,
or propyleneglycol for derivatives of propyl-
englycol.

In the case of polyglycols of high molecular weight, some manufacturers attach numbers to
their trade names, eg, the Union Carbide Co uses
such names as Carbowax 1540, Carbowax 4000
etc for their solid polyethyleneglycols. The Dow
Chemical Co calls their products: Polyglycol
E400, E600, E1200 and E4000.

Polyglycols were known in Germany as Poly-
glykol P-6, P-8, P-9, P-12, P-60 and P-80,
where P-6 etc refers to the units of ethylen
oxide used in the manufacture.

Glycols have been known since 1859, when
French chemist Wurtz (pronounced Wurtz) prep-
ed ethyleneglycol (See in this Vol, p E247-R). The
first polyglycol was prep by Lourenco in 1859
(See Diethyleneglycol in Vol 5, pp D1231ff).

Curme and Johnston (Ref 10, pp 7–10) gave a
fairly complete history of the development
and use of glycols in Germany and the USA. A
short historical background is given in this Vol
under "Ethylene glycol" and under other individ-
ual glycols.

The prep and props of the following glycols
and their derivs are given by Curme and John-
ston (pp 4–5), but only about 50% of these compds
are of interest from the Ordnance viewpoint:

**List of Glycols:**
- Ethylene glycol, HOCH₂,CH₂,OH;
- Propyleneglycol, CH₃,CHOH,CH₂,OH;
- Trimethyleneglycol, HOCH₂,CH₂,CH₂,OH;
- 1,3-butanediol, CH₃,CHOH,CH₂,CH₂,OH;
- 1,4-butanediol, HOCH₂,CH₂,CH₂,CH₂,OH;
- 2,3-butanediol, CH₃(CH₂OH)₂,CH₂,OH;
- 2-butene-1,4-diol (trans-form), HOCH₂,CH:CH,CH₂,OH;
- 2-butene-1,4-diol, HOCH₂,C:CH,CH₂,OH;
- 1,5-pentanediol, HOCH₃(CH₂)₃,CH₂,OH;
- 2,4-pentanediol, CH₃,CHOH,CH₂,CHOH,CH₃;
- 1,6-hexanediol, HOCH₂(CH₂)₄,CH₂,OH;
- 2,5-hexanediol, CH₃,CHOH(CH₂)₃,CHOH,CH₃;
- 2-methyl-1,3-pentanediol,
- CH₃,CHOH,CH(CH₃)₂,CHOH,CH₃;
- 2-methyl-1,4-pentanediol,
- CH₃,CHOH,CH₂,CHOH,CH₃;
- 2,3-dimethyl-2,3-butanediol (pinacol).

**Chemical properties of glycols.** They are similar
to those of aliphatic alcohols and the glycols
may be oxidized (in the vapor phase and in the
presence of catalysts) to the corresponding
acids. They are easily esterified by inorganic
and organic acids to form esters. Ethers (such
as methyl, ethyl etc) may be prep by treating
the glycols with alkyl sulfates in the presence of alkali (See Ref 10, "Subject Index", pp 370–71 and 381, under "Reactions")

Toxicity. The glycols and their polymeric derivatives have relatively low toxicity, but their nitrates are toxic. This subject is discussed in Ref 10, pp 300–327, under the title: "Physiological Aspects of the Glycols". It includes 125 refs. The toxicity of individual glycols is described briefly under each compd but it might be said generally that they are more or less toxic when taken orally or when mists or hot vapors of them are inhaled in large quantities. They irritate the skin to a certain extent, but do not seem to be absorbed very readily thru it. However, long exposures over large areas of the skin should be avoided. Some of the glycols and polyglycols are considered as safe for use in cosmetics and in pharmaceuticals and, in the case of propylene glycol, in foodstuffs (Ref 10, pp 300–327)

Uses.

Glycols and their derivatives are used extensively in industry and the household. The simple glycols are used in antifreeze solns for automotive cooling systems, commercial refrigerators etc. As liquid coolants, they are used in aircraft engines, machine

<table>
<thead>
<tr>
<th>Compound</th>
<th>LD₅₀ for Rate in g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetals</td>
<td>7.2</td>
</tr>
<tr>
<td>1,3-Butanediol</td>
<td>18.6</td>
</tr>
<tr>
<td>1,4-Butanediol</td>
<td>No data</td>
</tr>
<tr>
<td>2,3-Butanediol</td>
<td>&gt;5 (for rabbits)</td>
</tr>
<tr>
<td>Carbowa ex 1000</td>
<td>42</td>
</tr>
<tr>
<td>Carbowa ex 1500</td>
<td>44.2</td>
</tr>
<tr>
<td>Carbowa ex 1540</td>
<td>51.2</td>
</tr>
<tr>
<td>Carbowa ex 4000</td>
<td>59</td>
</tr>
<tr>
<td>Carbowa ex 6000</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Diethyleneglycol</td>
<td>20.8</td>
</tr>
<tr>
<td>2,2-Diethy-1,3-propanediol</td>
<td>No data</td>
</tr>
<tr>
<td>Dimethyl dioxane</td>
<td>3.0</td>
</tr>
<tr>
<td>2,3-Diethyl-2,3-butane-diol or Pinacol</td>
<td>No data</td>
</tr>
<tr>
<td>Dioxane</td>
<td>About 6</td>
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<tr>
<td>Dipropylene glycol</td>
<td>14.8</td>
</tr>
<tr>
<td>Ethers and esters of various glycols—See Cume &amp; Johnston, pp 305, 306, 309, 311, 313, 322</td>
<td></td>
</tr>
<tr>
<td>2-Ethyl-2-butyl-1,3-propanediol</td>
<td>3.0</td>
</tr>
<tr>
<td>Ethylene chlorhydrin (3.5g inhaled from the atmosphere killed a man)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Compound</th>
<th>LD₅₀ for Rate in g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyleneglycol</td>
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</tr>
<tr>
<td>Ethyleneglycol Dinitrate</td>
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<tr>
<td>2-Ethyl-1,3-hexanediol</td>
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<tr>
<td>Ethylene oxide</td>
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<tr>
<td>Glycolic acid</td>
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<tr>
<td>Glyoxal</td>
<td>2.02</td>
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<tr>
<td>2,5-Hexanediol</td>
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<td>2-Methyl-2,4-pentanediol</td>
<td>4.7</td>
</tr>
<tr>
<td>Polyethyleneglycol 200</td>
<td>34.0</td>
</tr>
<tr>
<td>Polyethyleneglycol 300</td>
<td>38.9</td>
</tr>
<tr>
<td>Polyethyleneglycol 400</td>
<td>43.6</td>
</tr>
<tr>
<td>Polypropyleneglycol (85% di-, 15% triglycol)</td>
<td>14.1</td>
</tr>
<tr>
<td>Polypropyleneglycol 425</td>
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<tr>
<td>Polypropyleneglycol 1025</td>
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</tr>
<tr>
<td>Polypropyleneglycol 2025</td>
<td>9.76</td>
</tr>
<tr>
<td>Propylene glycol</td>
<td>26.4</td>
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<tr>
<td>Propylene oxide</td>
<td>1.14</td>
</tr>
<tr>
<td>Propylene oxide tetramer</td>
<td>1.8</td>
</tr>
<tr>
<td>Triethyleneglycol</td>
<td>22.1</td>
</tr>
</tbody>
</table>

Trimethyleneglycol (about twice as toxic to small animals as propylene glycol)
guns and Amy tanks. Some derivatives of glycols are suitable gelatinizing agents for NC (See Ref 10, "Commercial Applications", pp 63–73 and 241–49).

Nitrated glycols, especially the lower members such as ethylene-, propylene-, triethylene-, and diethyleneglycol nitrates, are used in expl and propellant comps. Nitrates of the higher glycols, or polyglycols, were proposed as ingredients of Diesel fuels in order to raise their "octane number" (See Vol 2 of Encyl, p C145-R

Analysis and Test Methods.

Analytical procedures used in connection with glycols are described in the book by Curme and Johnston, pp 328–351 (54 refs are included) and under individual glycols in this Encyl.

The following glycols are described in this Encyl:

Buylegenol or Butanediols and Derivatives are in Vol 2, pp B368-R to B370-R; Diethyleneglycol and Derivatives are in Vol 5, pp D1231-R to D1233-L; Dipropylene glycol and Derivatives are in Vol 5, p D1497-L & R;

Ethylenglycol and Derivatives are in this Vol, pp E247-Rff

Trimethyleglycol and Derivatives is described as Dimethyolmethane or Propanediol in Vol 5, p D1355-L;

Propylene glycol and Polyglycols will be described under P’s;

Triethylene glycol will be described under T’s Refs: (See also under individual Glycols, such as Diethyleneglycol, Dipropylene glycol, Ethylene glycol, Propylene glycol, Triethylene glycol, Trimethylene glycol, Polyglycols)

2) P. Naoum (translated from German by E.M. Simms), "Nitroglycerine and Nitroglycerine Explosives", Williams & Wilkins Co, Baltimore, Md (1928), pp 210–239
3) A.L. Bernouilli & W. Kambli, Helv Chim Acta 16, 1187 (1933)
5) N.A. Milas & S. Sussman, JACS 59, 2345 (1937)
5a) K.B. Lehmann & F. Flury, "Toxicology and Hygiene of Industrial Solvents", Williams & Wilkins, Baltimore, Md (1943)
7) Hackh’s Dict (1944), 383
8) J.F.C. Garthorpe, BIOS Final Report No 360(1945)
9) P.W. Sherwood, Petroleum Refiner 28(3), 129; (7) 120 (1949)
10) C.O. Curme, Jr & F. Johnston, "Glycols", Reinhold, NY (1952) (ACS Monograph No 114 (1370 refs)

Additional Refs for Glycols:

A) H. Moureau et al, MP 28, 252–64 (1938) (Prepn of glycol starting from ethylene hydrocarbons)
B) P. Aubertine, MP 30, 7–42 (1948) & CA 45, 353 (1951) (The following nitrated glycols were prepared after WWII at the Laboratoire Centrale des Poudres, Paris: Ethyleneglycol dinitrate; Diethyleneglycoldinitrate; Triethyleneglycoldinitrate; 1, 3-Butanedioldinitrate; 1, 4-Butanedioldinitrate; and 2, 3-Butanedioldinitrate)
C) P. Aubertine, MP 41, 57–64 (1959) (Glycol and its nitrated derivatives)

Glycol Butylolether Acetate. See Ethylene glycol Butylolether Acetate in this vol, p E254-L

Glycol Condensation Products. See under Ethylene glycol Condensation Products in this vol, p E254-L

Glycol Dinitrate. See ETHYLENEGLYCOL DINITRATE in this vol, p E259-R
Glycol Dinitrate – Nitroisobutylglycol Dinitrate Mixtures. See Ethylenglycol Dinitrate – Nitroisobutylyl Dinitrate Mixtures in this vol, p E278-R

Glycol Dinitrate Polymers. See Ethylenglycol Dinitrate Polymers in this vol, p E278-R

Glycol Dinitrophenylether Nitrate. See under Ethylenglycolphenylether and Derivatives in this vol, p E279-R


Glycol-di-trinitrobutyrate (GTNB). See Ethylenglycol-di-trinitrobutyrate (EGTNB) in this vol, p E255-R

Glycol Esters and Ethers. See under ETHYLENGLYCOL AND DERIVATIVES in this vol, pp E247ff

Glycolformal. Same as Glycolmethylen Ether

Glycolglycolate Dinitrate. See Ethylenglycolglycolate Dinitrate in this vol, p E256-R

Glycolylguanidine. Same as Glycosyamidine

Glycol, Higher. Under the term "higher glycols" are known glycols contg four or more carbon atoms, such as 2,3-dimethyl-2,3-butane diol (pinacol), used as an intermediate in the manuf of synthetic rubber. Among other higher glycols may be mentioned some which were manufd, although in small commercial quantities, such as 2-methyl-2,4-pentanediol and 2-ethyl-1,3-hexanediol

Glycolic Acid and Derivatives
Glycolic Acid (Hydroxyacetic or Hydroxyethanoic Acid), HO.CH₂-COОH; mw 76.08; colorless, deliquescent crys; mp 78-79°; bp – decomp; sol in w, alc & eth. Can be prep by oxidation of glycol or by boiling chloroacetic acid with w or aqueous alkali (Ref 3). Its toxicity is discussed in Ref 2. Used as pesticide and plasticizer; its salts are used as catalysts (Ref 3)
2) Curme & Johnston (1952), 317
3) Cond-ChemDict (1961), 543-R

Glycolic Acid Azide, Glycolyl Azide, Hydroxy Acetazide or β-Hydroxyethonoylazide (Glykol-säureazid or Oxyzessigäureazid, in Ger), HO.CH₂.CO.N3; mw 101.07, N 41.58%, OB to CO₂ – 55.4%, OB to CO – 23.7%; bipyrantl crys, mp 189°; sol in eth. Can be prep by treating hydroxymethyldiazide in cooled HCl with aq Na nitrite. Explodes on heating (Refs 1 & 2)
Its ethyl, propyl and isoamyl esters are also expl comps (Ref 1)

Glycolic Acid, Methylester and Derivatives
Glycolic Acid, Methylester, HO.CH₂.CO.O.CH₃; mw 90.07; liq, sp gr 1.1677 at 18°, bp 151.2°, 63°(2mm Hg). Prepd by enclosed heating of sodium glycolate, methanol and chloroacetic acid methyl ester at 160°
Refs: 1) Beil 3, 236, (91) & [171] 2) L. Schreiner, Aan 197, 5 (1879)

Glycolinic acid, Methylester Nitrate,
O₂N.O.CH₂.CO.O.CH₃; mw 135.06, N 10.37%, OB to CO₂ – 41.4%; colorless liq, bp 165°(dec), 82.5°(28mm Hg), αD 1.4221 at 15°; sol in alc, benz & eth; insol in w. Prepd from the methyl ester and mixed acid, keeping the temp from rising much
Glycol, Monoethers of. Several monoethers of glycol, including isobutylenglycol-2-monoethyl ether, bp 140° and isobutylenglycol-2-monoethyl ether, bp 142° were prep'd and patented by Edlund. Can be used as solvents for cellulose esters, gums, resins etc.
Ref: K.R. Edlund, USP 1968032 & CA 28, 5832 (1934)

Glycol, Monophenylether of. See Ethyleneglycol Phenylether, also known as Phenyl "Cellosolve" in this vol, p E279-L

Glycolonitrile and Derivatives
Glycolonitrile or Glycolic Nitrile (Formaldehyde Cyanohydrin), HO.CH₂-CN; mw 57.05, colorless oil, sp gr 1.104 at 19°, fp p < -72°, bp 183° at 759mm (sl dec); v sol in w, alc & eth, insol in benz. Can be prep'd by treating formaldehyde with hydrocyanic acid. Used as solvent and org intermediate (Ref 3)
Following description about its expln is given in Ref 4: Less than 2 weeks after a double dist. from ethanol, glycolonitrile stored in a screw cap bottle polymerized, generating enough heat and pressure to shatter the bottle

Glycol Trinitrophenylether Nitrate. See under Ethyleneglycol Phenylether and Derivatives in this vol, p E279-R

Glycolurethane and Derivatives
Glycolurethane or Ethyleneglycolurethane, H₂N.CO.O.CH₂.CH₂.OH; mw 105.08; liq, sp gr 1.285 at 20°, bp 235°, 130-2° (1mm Hg), mp 30° (Ref 4), nD 1.4652 at 20°; sol in w & alc. Prepd by reacting ammonia with glycol carbonate, O.CH₂.NO.CO(O) at ambient temp.
N-Nitroglycurethane Nitrate,
\[ \text{O} \rightarrow \text{C}_2\text{H}_4\text{NO}_2; \text{mw} 195.05, \text{N} 21.54\%, \text{OB to CO}_2 - 12.3\%; \text{w} \text{crystals, mp 78.6\°C} \text{; sl sol in cold w, benz & chl; sol in hot w; v sol in alc, eth, acet & et acet.} \text{Can be prep'd in 79\% yield by adding glycolurethane (1 mole) to 8 mols 98\% nitric acid, with stirring at temp not exceeding 10\°C. Can be detonated by shock and is flammable. Used as gelatinizer for NC and as component of liquid & solid expl compns. Refs: 1) Beil, not found 2) G. Desseigne, FrP 1094959 (1955) & CA 53, 1159 (1959) 3) G. Desseigne, MP 43, 109-26 (1961) & CA 58, 6691 (1963)\]

Glycoluril or Glyoxalidureide, called in CA Tetrahydro-imidazo[4,5-d]imidazole-2,5(1H,3H)-dione. See ACETYLENEDIUREIN AND DERIVATIVES in Vol 1, p A65

Dinitroglycoluril. One isomer, 1,3-, prep'd by A.P.N. Fran chimoort & E.A. Klobbie, Rec 7, 18-19 & 246 (1888) and Rec 8, 290-91 (1889) is briefly described in Vol 1, p A65-R, while other isomer: Isodinitroglycoluril, also known as x, x'-Dinitroglycoluril is listed on p A66-L.

Although no later refs are found in CA thru 1971 for mono thru tetranitro derivs, the dinitrocompd was prep'd for NDRC by R.L. Shrinier and described in OSRD Rept 2054 (1943), pp 11-12. He nitrated glycoluril with concd nitric acid in presence of acetic anhydride at a temp of 5\°C. The yield was theoretical. He assigned to it the formula of 1,4-Dinitroglycoluril,

\[ O_2N\text{NC(O)}\text{NH.CH.N(NO}_2\text{)}\text{CO(NH)}\text{CH.} \]

The compd darkened at 305\°C without melting and burned quite rapidly, leaving little ash. It was sol in acet, sl sol in w or alc, insol in benz or chl. Its Ballistic Power was 101\% TNT, sensitivity near that of PETN and vacuum stability at 100\°C unsatisfactory. Was considered by Shrinier as unsuitable for military purposes.

Three dinitro isomers: 1,3-; 1,4-; and 1,6- were prep'd in 1952 by L. Minsky et al at PicArsn and described in Memorandum Report PAMP 16(1952)

Nitration of glycoluril with 100% nitric acid by the method similar to that of Franchi-mont & Klobbie yielded (84\% of theory) a mixt of 1,3-, 1,4-, and 1,6-isomers. The 1,3 isomer (10\% of total) was unstable and could be decomp'd by boiling water. The remaining mixt of 1,4- and 1,6-isomers was washed with ethanol and dried.

Procedure for Nitration. Add with stirring 10g of glycoluril (predried at 70\°C) to 100ml of absol nitric acid at RT. Warm the soln to 55\°C (in a water bath), while stirring for 1 hour, and pour slowly into 200ml of boiling w. The resulting evoln of gas is caused by decompn of 1,3-isomer. Cool the slurry in an ice-bath to 0\°C, filter off the ppt, wash it with ice-cold w until neutral to litmus, followed by rinsing with ethanol and drying.

The resulting mixture of 1,4- and 1,6-Dinitroglycolurils had mw 232.12, N 36.21\%, OB to CO_2 - 27.6\%, OB to CO 0\%, mp - defigr betw 270 & 280\°C (vs 475\°C for TNT). Franchimont & Klobbie gave 217\°C as defigm temp (probably for impure compd). Brinsaid by Sand Test 42.1g sand crushed, vs 48g for TNT (minimum detonating charge of Tetryl was 0.089g).

Heat of Combustion at C_\nu 1901cal/g.

Heat Test at 100\°C. Loss in wt 0.41\% 1st 48 hrs, 0.02% 2nd 48 hrs and no expn.

Impact Sensitivity by BushMinesApp. 2kg wt - 50cm, vs 60-100 for TNT and by PicArsnApp 7 inches, vs 14 inches for TNT.

ISP (Calculated). Specific Impulse of gases 197 lbs, sec/1b, vs 215 for Guncotton (13.15KN).

Vacuum Stability Test at 90\°C. 0.25cc gas evolved by 1g in 40 hrs, vs 0.10cc for TNT.

Tetranitroglycoluril or Tetranitroacetelyenediurein. The compd was prep'd and investigated in 1952 at Picatinny Arsenal by L. Minsky et al and described in Memorandum Report PAMA 16(1952):

1,3,4,6-Tetranitroglycoluril,

\[ O_2N_2\text{NC(O)}\text{NH.CH.N(NO}_2\text{)}\text{CO(NO}_2\text{)}\text{CH; mw 322.06, N 34.78\%, OB to CO}_2 + 5.0\%; hygroscopic crysts, mp - decomp ca 225\°C; sol in NMe, decomp by w & hot ethanol; insol in glacial AcOH, eth, dioxane, toluene or xylene.\]
Can be prep'd by nitration with HNO₃ + P₂O₅ of either glycoluril or its dinitro compd.

Procedure: Add quickly with stirring 10 g of glycoluril (preried at 70°) to a mixt (preheated to 50°) of 150 ml absol HNO₃ and 15 g P₂O₅, contd in a 3-neck 300-ml round bottom flask, provided with thermometer, stirrer and reflux condenser. After stirring for 1.5 hours at 50°, cool the flask with contents in an ice bath to about 0° and pour the contents slowly on about 250 g of crushed ice. Leave standing overnight in a cold place, then filter and wash the ppt with ice-cold w until neutral. Finally wash with ice-cold ethanol, then with ice-cold ether and dry the crysts in air. The usual yield was 30% of theory.

Note: When nitratating dinitro- to tetranitrocompd, reduce the amt of HNO₃ to 100 ml, the amt of P₂O₅ to 14 g and the time of stirring at 50° to 1 hour.

Tetranitroglycoluril is an expm ore bris- sant than TNT, but comparable to PETN. It is extremely sensitive to impact and of inadequate thermal stability.

The following props were dedd at PicArsn:
Brisance by Sand Test. 61.9 g sand crushed (vs 48.0 for TNT & 62.7 for PETN)
Explosion Temperature. 133° (vs 225° for PETN)
Heat Test at 75°, exploded in 30 minutes
Impact Sensitivity, 2 kg wt, PicArsnApp, 2 inches (PETN 6 inches)
Impact Sensitivity, 2 kg wt, BurMinApp, 6 cm (PETN 17 cm)
ISP (Specific Impulse of gases), calcd 195 lbs., sec/lb, vs 215 for NC (13.15% N)

Glycolyl. The monovalent radical HO.CH₂.CO- or divalent radical =C₂H₂O

Glycolyl Azide. See Glycyllic Acid Azide under Glycolic Acid and Derivatives in this vol

Glycolylurea and Derivatives. See under Hy- dantoin and Derivatives in Vol 7 of Encycl

Glycoside. See Glucooside

Glykol. Ger for Glycol

Glyoxal or Ethanediol, O:CH.CH₂.O; mw 58.04, yel crysts, sp gr 1.14 at 20°(1.26 at 20/20°), mp 15°, bp 51° at 776mm, nD 1.3826 at 20°. Its vapor is green and burns with a violet flame; sol in w, alc & eth. Was first prep'd in 1881 (Refs 1 & 2) by oxidizing acetaldehyde with nitric acid. This and other methods are described by Curme & Johnston (Ref 4, pp 125-26).

It polymerizes on standing or in presence of trace of w, forming "trimeric glyoxal".

Its toxicity is discussed by Curme & Johnston (Ref 4, p 317). In skin absorption it is about 1/10th as toxic as formaldehyde.

The industrial utilization of glyoxal is largely based on the advantage which may be taken of its two aldehyde groups, its lack of volatility from aqueous solns, and its inoffensive color. Among its uses may be cited insolubilizing of proteins, polyvinyl, alcohol, starch, etc (Ref 4, p 127) (See also Ref 5). The use of its commercial aqueous solns was reviewed by Bohmfalk (Ref 3)

3) J.F. Bohmfalk et al, IEC 43, 786(1951)
4) Curme & Johnston (1952), 125-28 & 317
5) CondChemDict (1961), 545-L

Glyoxaldioxime. See Glyoxime in this Vol

Glyoxaline (or Imidazole) and Derivatives. See 1,3-Diazole and Derivatives in Vol 5, pp D165-R & D166-L

Glyoxaline or Glyoxyline. A Dynamite patented in 1867 by F. Abel: NG 65.5, NC 30.0, K nitrate 3.5 & Na carbonate 1.0% (Ref 1).

Accdg to Naoum (Ref 3), Abel saturated a mixt of K nitrate and Guacotton and called the product "Glyoxilin". Accdg to Daniel (Ref 2), Broderson patented in 1867 in England a similar compn, but it never was used in practice
Glyoxime and Derivatives

Glyoxime, Glyoxalidoxime or Oximinoacetaldoxime, HON:CH(CH):NOH; mw 88.05, N 31.82%, OB to CO₂ –72.7%, colorless plates (from w), mp 176* (dec at 172*); sol in hot w, alc & eth. Can be prep'd from glyoxal (1 mol) and hydroxylamine hydrochloride (2 mol)
Refs: 1) Beil 1, 761–2, (394) & [818]
2) M. Wittenberg & V. Meyer, Ber 16, 505 (1883)

Nitroglyoxime (Nitro-oximino-acetaldoxime, in Ger), HON.CH(NO₂):NOH; mw 133.03, N 31.58%, OB to CO₂ –18.00%; ndls (from w or other solvants), mp ca 111* (dec), bp – expl on heating above mp; sol in w, decomps in hot and imparting to the soln a strong acid reaction; sol in alc, eth & acet; v sl sol in cold benz, more in boiling benz; insol in chlf & petr eth. Can be prep'd by treating an ethereal soln of glyoxime with fuming nitric contg NO₂ or by treating glyoxime with NO₂ alone.

It is an expl compd. Being acidic, it forms salts on being treated with bases. The following are expls:

Hydrazine Salt, C₂H₅N₂O₄.N₂H₄; brick-red pdl, mp 95* (dec), puffs off at higher temp; sol in w & hot alc; sl sol in cold alc; insol in eth & chlf; dissolves in acet with decomps (Ref 2, p 2750)

Lead Salt (Basic),
(C₂H₅N₂O₄)(Pb.O.PB(C₂H₂N₂O₄), yel solid, mp – expl on heating. Was prep'd by adding an aqueous soln of Pb acetate toaq soln of Nitroglyoxime (Ref 2, p 2750)

Potassium Salt, C₂H₅N₂O₄.K, brownish-yel ndls (from abs alc), mp (explodes on heating) (Ref 2, p 2748)

Silver Salt, C₂H₅N₂O₄.Ag + H₂O, red ndls, mp (dehydrates on heating) (Ref 2, p 2748)

Gmelin, L. (1788–1853). German chemist noted as the author of now known as “Gmelin’s Handbook der anorganischen Chemie”
Refs: 1) Hackh’s Dict (1944), 385-L

Gnom. A pocket size magneto-electrical exploder manufd by Schmitt & Co at Küppertesg (Germany) during the 2nd half of 19th century. Its illustrated description is given in Ref Reff: Daniel (1902), 243–44

“Gob” Fires in Coal Mines. Under this name are known spontaneous combustions in coal mines arising in waste (gob) piles. When the area had been partially or completely sealed off, the heat could distil combustible gases from residual coal in the vicinity and create an expl mixture if the available oxygen had not been depleted at too fast a rate. An odor known as “gob stink” sometimes served as a warning to workers of the existence of one of these fires
Refs: 1) T.N. Mason & F.V. Tideswell, “Safety in Mines Research Board”, GB Britain, Paper No 75 (1933) & CA 27, 2813 (1933)

Goddard, Robert H. (1882–1945). American scientist, who is considered in the USA as the father of modern rockets. He worked mainly on the mechanical aspects of rockets but also made important developments in rocket fuels
Refs: 1) Willy Ley, "Rockets, Missiles and Space Travel", Viking, NY (1957), pp 107–08
2) Rocket Encycl (1959), pp 191–95 (More detailed description of Dr Goddard's education, contributions, and more than 200 patents in rocket engineering)

GOER Vehicles are all terrain, floatable wheeled vehicles consisting of a front power unit and a trailing functional unit – 8 ton cargo, 2500 gal tanker, or 10 ton wrecker. These were given some field experience in the Vietnamese arena, and are undergoing further testing. The normal suspension system has been dispensed with, the function absorbed by the 10-ply 18.00 x 33 tires which also serve to give the necessary ground clearance. Manufacturer is Caterpillar Tractor Co. Ref: J.B. Hayes, NatlDefense (formerly Ordnance), 58, 115, Sept-Oct 1973

Gootz Powder. K chlorate 34.5, glucose 34.5, Pb picrate 10.3, charcoal 10.3, sulfur 6.9 & amorphous phosphorus 3.5%
Refs: 1) Daniel (1902), 355 2) Giua, Trattato 6(1)(1959), 400


Gomex Powders. Mixtures of K chlorate and nitrate with Pb nitrate and acetate
Refs: 1) Daniel (1902), 356 2) Giua, Trattato 6(1)(1959), 396

Gomme (Fr for Gum). In the Fr and Belg expls industry, it is a general term for gelatin expls (gelatines explosibles) consisting of NG gelatinized by NC, so which an alkali or Amm nitrate and carbonaceous material may be added.

Following is the list of such expls:
Gomme A: NG 92 & NC 8% (Corresponds to Amer Blasting Gelatin)
Gomme B: NG 83, NC 5, K (or Na) nitrate 10 & sawdust 2%
Gomme B AM: NG 60, NC 3, Amm nitrate 31 & cellulose 6%
Gomme C: NG 74, NC 6, K (or Na) nitrate 15.5 & sawdust 4.5%
Gomme D: NG 69.5, NC 5.5, K nitrate 24.75 & Na carbonate 0.25%
Gomme de Cugny or Gomme E: NG 49, NC 2, Na nitrate 36, sawdust 10 & flour 3%
Gomme J or Gomme à 92: Same as Gomme A
Gomme M: NG 74, NC 6, K nitrate 15.5, flour or woodmeal 4 & Mg oxide 0.5%
Gomme MB: NG 70, NC 4, K nitrate 16, flour or woodmeal 9,5 & Mg oxide 0.5%
Gomme N: NG 25, NC 1, K nitrate 10 & Amm nitrate 64%
Gomme NB: NG 25, NC 1, Na nitrate 10 & Amm nitrate 64%
Gomme en nitrate d'ammoniaque: NG 37.5, NC 2.5, Amm nitrate 55 & cereal flour 5%
Gomme incongéable de la Nobel française: NG 75, NC 5, K (or Na) nitrate 10, DNT 8 & sawdust 2%
Gomme incongéable de la Société d'Explosifs et de Produits chimiques: NG 64.4, NG 46.6, NC 5, K (or Na) nitrate 10 & sawdust 2%
Gomme supérieure or Gomme extraforte. Same as Gomme A
Gomme de sûreté de Cugny; Gomme NP: Same as Gomme N (above) and Gomme NS - same as Gomme NB (above)
Refs: 1) L. Lheure, MP 11, 222–24 (1901)

Gonflement, Coefficient de. Fr for Swelling Coefficient. See Coefficient de gonflement in Vol 3, p C389-R

Gomme (Cannon). The earliest weapon using BlkPdr, including cannon, hand cannon, pot de fer & tottempgel, dates from around 1300. Gommes were slow to evolve. The monsters lacked mobility, the little bombards or muskets or arquebuses shot a weak chge. Both took a long time to fire. In time, the gomme did improve, but their military application took many years longer. Although cannons are recorded as being used in land action at Seville in 1247,
it was a century later (1351) in naval action between the Moors & Spanish that ship cannons won the battle. The Moors are recorded as using guns against Christians of the Alcazar in 1343. Venetians are supposed to have employed guns against the Genoese in 1380

See also CANNON in Vol 2 of Encycl, pp C26-Lff

Gooch, Frank Austin (1852–1929). An American chemist, noted for analytical methods, especially as the inventor of "Gooch Crucible". It is a crucible with perforated bottom packed with glass wool or asbestos and placed in a funnel inserted in the stopper of vacuum flask. Can be used for filtering corrosive liquids
Ref: Hackh's Dict (1944), 386-L

Goodyear Powder. Black Powder, patented in England in 1865, contd salt peter, sulfur, charcoal, and a small quantity of caoutchouc or gutta percha
Ref: Daniel (1902), 356

"Goop" is the name given to the crude intermediate product obtb in the manuf of magnesium at the Henry Kaiser plant. It consists of a mixt of ultrafine particles of Mg, Mg carbide, magnesia, carbon, naphtha & asphalt, all in the form of thick paste. The material proved to be a suitable source of Mg in prep of incendiary compns for bombs. The most successful of such mixtures was known during WWII as Pyrogel or PT-1

Goriunov, P.M. (1901–1943). Russian engineer who designed some automatic weapons, such as machine gun SG-43 (Stankovaya Goriunova-43)

Ref: Anon, MAF 15, after page 646, pp 1 to VI (1936)

Gotham Explosive (Amer) consisted of NG 66, K chlorate 20, K nitrate 4 & pulverized cinchona or oak-tree bark 10%
Ref: 1) Daniel(1902), 356 2) Giua, Trattat 6(1)(1959), pp 344 & 400

Goudron. Fr for tar or pitch
Note: Accdg to "New Century Dictionary" (1948), Appleton Century Crofts, NY, the name "goudron" was given to a bundle of sticks soaked in pitch, oil or the like and used either for lighting or setting fire to enemy's work

Government Book Stores

The US Govt sells publications thru three outlets. All purchases must be prepaid. While GPO deals in general publications, occasional titles will be of interest to the explosives and pyrotechnics industry

GPO – Superintendent of Documents
US Govt Printing Office
Washington, DC 20402

DDC – Defense Documentation Center
Cameron Station
Alexandria, Va 22314

NTIS – National Technical Information Service
US Dept of Commerce
Springfield, Va 22151

The two technical houses are DDC and NTIS. DDC used to be ASTIA. It handles classified or otherwise restricted documents and you must be registered there. This is important. If you are not registered, write for information but don't waste time asking for documents. (Limited documents — numbers followed by the letter L — require additional approval by the issuing agency). NTIS used to be Clearinghouse.
It sells open material. Documents in both collections are indexed, the indexes being available in most technical libraries. Most documents from DDC and NTIS cost $3 for hard copy and 95¢ for microfiche, while GPO publications are priced individually.

Ref: G. Cohn, Expls & Pyrots 5(12), 1972

GPF (Abbrn for Grand Puissance Filoux). French heavy artillery weapon (such as 155-mm cannon), successfully used during WWI.


Gräbe (or Groebe), Carl (1841–1927). A German org chemist who established the constitution of naphthalene, anthracene and phthalic acid, etc. Co-synthesized with Carl Liebemann (1842–1914) alizarine. Ref: Hackh’s Dict (1944), 386-R (Graebe); 490-L (Liebemann)

Grageroff, I.A., Dr (1880–1962). Russian-American chemist, an authority in many branches of explosives. Worked for some time at Apache Powder Co, Benson, Arizona and then during WWII as the Director of Operation of one of the largest TNT Plants in the US located at Meadville, Pennsylvania. Introduced a method of manuf of TNT which speeded up the production threefold and resulted in considerable economy. Ref: B.T. Fedoroff, who worked before and during WWII under Dr Grageroff

Grade Construction. The use of explosives for grading work can be divided into the following classifications: 1) clearing and grubbing; 2) ditching and drainage; 3) excavation; 4) fill settlement; 5) production of surfacing material and ballast. As a result of rapid development of drilling equipment (percussion and rotary type machine) borehole diameters of 2½ to 5 inches are used, but larger holes are possible. Types of explosives applicable to highway blasting include Forty per cent Dupont Gelatin, Gelex 1 or 2 and Red Cross Extra. Nitramon and Nitramite are used for large holes on highway work. For small dry work Nitramite FR is used considerably, also Nilite and Ammonium Nitrate prills and oil can be used under similar conditions if the holes are large enough. Open face shooting requires less explosives, the factor depending largely on the type of rock. Factors usually run 0.50 to 0.75 pound per cubic yard. The result of use of MS delays in grade construction is improved fragmentation and decreased vibration. In addition, they aid in controlling the direction and amount of throw of the broken rock. Primacord and MS connectors are used instead of MS delays for greater safety when spacings between holes are large enough to minimize the chance of cut-offs. For firing, two sizes of condenser discharge type of blasting machines known as CD-32-1 and CD-48-1 with capacities up to 480 and 1200 blasting caps, respectively.


Graham, Thomas (1805–1869). A Scottish chemist, pioneer in the study of colloids, the diffusion of gases and dialysis. Developed so-called Graham Law which states that velocities of diffusion of any two gases are inversely proportional to the square roots of their densities. Ref: Hackh’s Dict (1944), 386-R

Graham Explosive. It was prep’d and used in a moist condition in the form of a paste consisting of KCl 51.8, sugar 25.9, K₄Fe(CN)₆ 20.7 & Pb₃O₆ 1.6%.

Ref: 1) Daniel (1902), 356 2) Gua, Trattato 6(1), 1959, p 400

Grain. A unit of the apothecaries, avoidus or troy weights (originally that of an average wheat grain), approx equal to 0.0648 gram (Ref 1). In Ordnance, a single piece of a solid expl or solid prop, regardless of size or shape, used in a gun or a rocket (Ref 2).

(See also Grains of Smokeless Propellants)
Grains of Smokeless Propellants. Smokeless propellants are forms of Nitrocellulose expls with various organic and inorganic additives and are used as proplnts. They are divided by compass into classes of which the single-base and double-base are the most common. They are manufd in quantity in a variety of shapes (Fig) (Ref 2). Cylindrical grains are made in various diameters and lengths depending on the size of the gun. Perforations shown in Fig are for controlling the rate of gas liberation as well as burning time. At constant pressure, the time of burning is proportional to the amount of exposed powder surface, therefore the propnt is made into accurately sized grains of selected shapes (Refs 1 & 3).

Proplnt grains in the shape of ball, strip, cord and pellet are of degressive granulation because their surface area decreases during burning (Ref 2, p 91-L). Single-perforated proplnt grains are of neutral granulation because their surface area remains constant during burning (Ref 2, p 194-L). Multiperforated and rosette proplnt grains are of progressive granulation because their surface area increases during burning (Ref 2, p 223-R).

Refs: 1) Hackh’s Dict (1944), 387-L 2) Glossary of Ordn (1959), 137-L

Grain Dust Explosions. See under Dust Explosions in Vol 5 of Encycl, p D1578-L

Graining is the process of forming material into smaller particles than the original material. One of such processes, prilling or spray graining, used in manuf of AN, is described in Vol 1 of Encycl, p A314-R. Very often graining can be accomplished by crushing and grinding as described in Vol 3 of Encycl, pp C564-R to C567-L (Compare with Grist and with Granulation)

Graining of Smokeless Propellants (Grenage, moulage, étirage ou filage des poudres colloïdales, in Fr). This operation is one of the steps in the manuf of smokeless propellants. It is briefly described in Vol 3 of Encycl, under “Colloiding Agents and Colloidal Propellants”, p C399-R for single-base propellants and p C400-L & R for double-base proplnts [See also Davis (1943), 302-04]

French method is described by Pepin Lehalleur (1935), 298-99, under the title “Moulage ou étirage”

FIG. Typical Shapes of Powder Grains
Granadilla. Ger for Bursting Charge for Shells

Granatfylling 88 or Grf 88. Ger name for Picric Acid (PA), which started to be used for Ger Shells in 1888

Granatfylling 02 or Fp 02. Ger name for TNT (Trotyl), which started to be used as filler for Ger Shells in 1902

Granatprobe. Ger for Fragmentation Test

Grandcamp Explosion. An explosion of 2300 tons of Ammonium Nitrate (AN) fertilizer, which took place aboard the SS Grandcamp on April 16, 1947, while the ship was being loaded in the harbor at Texas City, Texas. The explosion was started by a fire in one of the holds.

As a result of the explosion, a fire developed in one of the holds of the SS High Flier (moored 600 ft away from the Grandcamp), containing sulfur. This fire spread to one of the holds containing 960 tons of AN which exploded on April 17.

These explosions caused a loss of life of 600 persons and property damage of about $50 million.

Ref: PATR 2700, Vol 1 (1960), pp A359-L to A361-R and Refs 54 to 64, listed on p A363-L

Gronadizing Process, developed by the American Chemical Paint Co, Waterbury, Conn for rust prevention of iron, steel, zinc or cadmium consists in immersing the material in a hot solution of acid zinc phosphate. This operation forms an acid resistant coating. The resulting material may be painted.

The process is fundamentally the same as “parkezing”

Granular Explosives of Whetstone. A Dynamite is made by emulsifying a molten HE, such as TNT, by the aid of an emulsifying agent, such as agar-agar, in the melt comprising AN and at least one compd nonvolatile at the temp of the melt and which lowers the mp of the AN such as Ca(NO₃)₂, 4H₂O, Pb(NO₃)₂, alkali-metal nitrate, Mg(NO₃)₂, 6H₂O, anhyd NaCl, Na benzeno sulfonate, sucrose, acetamide, urea or dicyanodiamide. The emulsion freezes at above 46° and is free from uncombined water.

Refs: 1) J. Whetstone, BritP 597716 (1948) & CA 42, 4349 (1948) 2) J. Whetstone, USP 2460375 (1949) & CA 43, 2776 (1949)

Granular Smokeless Propellants. An improved smokeless propellt is produced by providing a central perforation with or without radial slots in addn to porosity produced by leaching out a water-sol crst ingredient. Thus, a propellt compn is made from colloided NC (13.25% N) 100, Pb₂NH 1.1 & KNO₃ 45–50 parts with the aid of a volatile solvent, and is extruded thru a die so as to produce the central perforation with or without radial slots.

Refs: 1) S. Gordon, BritP 626955 (1949) & CA 44, 3528 (1950) 2) S. Gordon, USP 2575871 (1951) & CA 46, 2299 (1952)

Granulation of an Explosive or Propellent. The size of the grains can be ascertained by sifting the material thru a series of sieves with different sizes of aperture and weighing the proportions retained on each sieve (Ref 1).

The sieves used in the USA are US Natl-BurStds Sieves. They are listed in Table 1, p A674 of Ref 2 in comparison with Tyler, British and German Sieves.


Granulation Process. It is an act of forming solid material into particles of desired size and shape, usually of larger size than original powder. It is one of the branches of "size enlargement" and differs in this respect from the "size decreasing". Very often no distinction is made betw the terms "granulation" and "graining".

The methods of producing granules from powdery substances may be subdivided into:
a) Granulation with a binding agent consists in moistening the powder with a binding soln, followed by screening, rotary drying etc
b) Granulation by fusion consists in agglomerating the material contg binding agents such as pitch, paraffin, wax etc, into sheets, followed by cooling and reducing to granules of the desired shape. Sometimes, material can be fused directly to granules of the desired shape.
c) Granulation by briquetting consists in agglomerating the powdered material into small size briquettes, also called "slugs", followed by grinding and screening.
d) Granulation by spray drying consists of suspending the material in a liquid and spraying the suspension thru a nozzle into a drying chamber by means of hot compressed gas.
e) Granulation by the Cabot spherizing process consists of subjecting the material to turbulent mechanical action in mixers with specially designed agitators. The material gradually agglomerates into spherical form with large reduction in bulk density. The process can be usually speeded up by using small spherical "starters" sifted from the previous batch.
f) Granulation by dissolving a solid material in a liquid and running the solution in a thin stream into another liquid which is nonsolvent for the solid, but is miscible with the first liquid. For instance, TNT or NC may be dissolved in acetone and then run into water.
g) Granulation by melting of a solid material and running it thru a screen situated on the top of a tower, down which the material flows. This method can be used for the prepn of shot.

One of such towers may be seen in Baltimore, Maryland.

h) Granulation by Olsen process, used in the prepn of BALL POWDER. Process is described in Vol 2 of Encycl, PATR 2700 (1961), pp B11-R to B16-L.

Ref: Perry (1950), 1187–88; and (1963), pp 8-60ff

Granulite. A British, large, irregular-grain, smokeless proplnt consisting of NC 46.3, Ba nitrate 45.3, paraffin 7.8 & moisture 0.4%. 

Grate. A bed of coals and coke, or charcoal, with spaces that are required for the passage of hot gases.
Paraffin was used for coating the grains
Ref: Daniel (1902), 357

Granulometry of Explosives. Denomination of granularity by sieving is often thought to be imprecise. However, it is possible to make the measurement precise if certain precautions are observed. In particular, the product must spread out smoothly on the screen without flying out, and sieving must be continued until nothing is left. Manual sieving is satisfactory, but faster, more precise results are obtained with a mechanical sieve. The crystals of many explosives are electrified by friction during sieving. This seriously affects the results. Add of 1 or 2% of graphite helps in some cases. For fine powders, accurate results can be obtained only if the sieving is done under water.
Ref: P. Aubertin, MP 37, 139-48 (1955) & CA 50, 17453 (1956)

Grape-shot or Case-shot. Accdg to Greener (Ref 1), most of the early firearms shot arrows, stones, and iron shots, but in Germany the mortars were filled up with small stones about the size of walnuts, the first form of what was afterwards long known as grape shot, also called hail-shot. Some Ger states forbade the use of these shots.

Marshall (Ref 2) states the following: "Formerly case shot was used against troops at short range. It consisted of a case containing a large number of bullets, which spread out from the muzzle of the gun, the case being broken up in the bore. The principal case shot were grape, canister and shrapnel case. They are not used much now and their place has been taken by shrapnel shell (invented in 1794 by Lt of Brit Army Shrapnel), and machine guns.

There was also so-called chain-shot, said to be invented in Holland by De Witt, about 1666. It consisted of two balls or half balls united by a chain. It was fired against the rigging of ships.

One type of grape-shot consisted of a number of cast-iron balls, about the size of grapes, packed in layers in a cylindrical container, equalizing in diam the bore of the gun. A round usually consisted of 9 balls in nema of three. The breaking of the cylinder discharged the shots in all directions (See also "Canister" in Vol 2 of Encyc, p C244-R)

Graphic Methods. Pencil and paper methods that employ the geometry of a plane to express mathematical relationships and to carry out mathematical operations in analog form. Some topics under this definition are plotting of experimental data, curve fitting and development of empirical formulas, graphical interpolation and extrapolation, nomographs and alignment charts, graphical differentiation and integration, graphic statics.

Graphigen Rocket Fuel. See under Graphite-Containing Rocket Fuel

Graphite (Black Lead, Plumbago, Mineral Carbon), C, at wt 12.01, d 2.25, mp 3527°; hardness by Mohs scale 1 to 2. Black, cubic crystals with metallic lustre; when in powdered form it is steel-gray to black in color with a dull metallic lustre. It occurs in nature in many places. The best grades of commercial graphite are from Ceylon. It may also be prepared artificially by heating other forms of carbon in an electric furnace. It is insol in any of the known solvents, but is sol in molten iron. It is not attacked by some strong oxidizing agents with formation of "Graphitic Oxide" (See under). If the oxidation of graphite by nitric acid is conducted in the presence of catalysts, such as vanadic acid or silver nitrate, mellitic acid, C_{12}O_{12}H_{n}, is obtained.

Graphite is used extensively in commerce. In the expl industry it is used for glazing grains of Bk Pdr and smokeless propellants in order to render them less hygroscopic and
make them electrically conductive, so that they cannot accumulate static charges. Graphite used in the manuf of smokeless propellants should be quite free from sulfides and acids and should contain only a trace of silicates (Refs 1 & 2)

Graphite has found application in the prep of Tetryl pellets. In this case, a small quantity of powdered graphite is mixed with powdered Tetryl and the mass is pelletted. The presence of graphite eases this operation because it makes the Tetryl less sticky (ie graphite acts as a pellterizing lubricant).

Some uses of graphite as an ingredient of expls, propellants, and pyrotechnic combs are listed in Vol 2 of Encycl., under CARBON, pp C54-L to C55-R and in some Refs of pp C55-R to C56-R.

Electronic properties of graphite are described in Vol 8 of Ref 6, while its thermal props are in Vol 10. In Vol 11 is described highly oriented pyrolytic graphite.


Graphite, Colloidal. It may be either natural or artificial graphite ground to 1 micron particle size, coated with a protective colloidal, and dispersed in a liq. One selects the liq carrier - water, oil, or synthetics - for the use intended. The two outstanding props of colloidal graphite dispersions are: 1) the particles remain in suspension and 2) the particles "wick", ie are carried by the liq to most places the liq penetrates Ref: Clark & Hawley (1966), p 495 (Graphite by S.B. Seeley.

Graphite-Containing Rocket Propellants.
Graphite rocket fuel is prep'd from graphite, K perchlorate and 90 nitric acid. Thus, 100g finely divided graphite is added 300g K perchlorate and sufficient amt of 90 nitric acid to yield a liquid mass. The reaction mass is allowed to stand for 4-6 days with nitric acid renewed 4-5 times as it is absorbed. The product, graphite, is dried at RT and stored in the dried state at RT. Before use in a rocket, the graphite is soaked in 35% C6F6 for several hrs. ErA11 in a glass-lined jet container under argon pressure sprayed on the graphite simultaneously with Amm chloride in liquid ammonia is the other component of the hypergolic system Ref: S.L. Ruskin, USP 2944881 (1960) & CA 54, 25832(1960).

Graphites shall be of the following grades:
Grades I & III - manufactured
Grades II & IV - natural
Grades I & II are intended for use as lubricants in pellterizing expls
Grades III & IV - as glazing agents
3. REQUIREMENTS:
See Table 1 on following page
3.1 Appearance (applicable to Grade II and IV only). Graphite of grades II and IV shall appear steel gray or silver gray in color and shall have a metallic luster.
3.2 Properties. Graphite shall conform to the limits for the properties specified in Table 1, when determined as specified in the applicable sub-paragraphs of 4.3.
3.3 Lubricating quality (applicable to Grade I and II only). When specified, Grade I and II graphite shall be tested for use as a pellterizing lubricant as described in paragraph 4.2.2.1.
### Table I

<table>
<thead>
<tr>
<th>Properties</th>
<th>Grade I percent</th>
<th>Grade II percent</th>
<th>Grade III percent</th>
<th>Grade IV percent</th>
<th>Paragraph</th>
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<td>-</td>
<td>-</td>
<td>96.0</td>
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</table>

3.4 Glazing quality (applicable to Grade III and IV only). When specified Grade III and IV graphite shall withstand the glazing test specified in paragraph 4.2.2.2

4. QUALITY ASSURANCE PROVISIONS

4.1, 4.2, 4.2.1 & 4.2.2 - See p 2 of Spec

4.2.2.1 Pelletizing Quality (Applicable to Grade I and II). Mix two parts by weight of the sample and 100 parts by weight of Tetryl, complying with the requirements of Specification JAN-T-339. Make at least 25 pellets of the mixture by subjecting portions of the mix to pressure in a pelletizing machine. Note: The graphite shall be considered satisfactory if the machine works smoothly and easily, if the powder does not stick to any parts of the machine, and if the resulting pellets do not fall apart

4.2.2.2 Glazing quality (applicable to Grade III and IV). The graphite shall be subjected to an actual factory glazing operation and to such additional tests as shall be considered necessary by the contracting officer.

4.2.3 and 4.2.4 - See pp 3.4 of Spec

4.2.5 Testing. The lot shall be sampled and specimens selected for testing by the following procedure:

4.2.5.1. Sampling. Select 10 percent of the containers in the lot. If there are less than 100 containers in the lot, select 10 containers. If there are less than 10 containers in the lot, all containers shall be selected. Remove a portion of approx 2 oz of material from each container. Mix thoroughly each of the prev

3.4 Glazing quality: When specified, Grade III and IV graphite shall withstand the glazing test specified in paragraph 4.2.2.

4. QUALITY ASSURANCE PROVISIONS

4.1, 4.2, 4.2.1 & 4.2.2 - See p 2 of Spec

4.2.2.1 Pelletizing Quality: Mix two parts by weight of the sample and 100 parts by weight of Tetryl, complying with the requirements of JAN-T-339. Make at least 25 pellets of the mixture by subjecting portions of the mix to pressure in a pelletizing machine. Note: The graphite shall be considered satisfactory if the machine works smoothly and easily, if the powder does not stick to any parts of the machine, and if the resulting pellets do not fall apart.

4.2.2.2 Glazing quality: The graphite shall be subjected to an actual factory glazing operation and to such additional tests as shall be considered necessary by the contracting officer.

4.2.3 and 4.2.4 - See pp 3.4 of Spec

4.2.5 Testing: The lot shall be sampled and specimens selected for testing by the following procedure:

4.2.5.1 Sampling: Select 10 percent of the containers in the lot. If there are less than 100 containers in the lot, select 10 containers. If there are less than 10 containers in the lot, all containers shall be selected. Remove a portion of approx 2 oz of material from each container. Mix thoroughly each of the pre:
in a desiccator and weigh. Retain the residue for the silica and other grit dems as specified in 4.3.3 and 4.3.4. Calculate the wt of residue as percent ash as follows:

\[
\text{Percent ash} = \frac{100 \times A}{B}
\]

where:

\[
A = \text{wt of residue}
\]
\[
B = \text{wt of specimen}
\]

4.3.3 Determination of Silica (Applicable to Grade II & IV only). To the ash in the platinum crucible, add 5 ml of HCl and a few drops of sulfuric acid. Evaporate and ignite. Cool in a desiccator and weigh. Calculate the loss in weight as percent silica as follows, and retain the residue for grit dems:

\[
\text{Percent silica} = \frac{100 \times (A - C)}{B}
\]

where:

\[
A = \text{wt of residue as found in 4.3.2}
\]
\[
B = \text{wt of specimen}
\]
\[
C = \text{wt of residue after treatment}
\]

4.3.4 Determination of Other Grit

4.3.4.1 Applicable to Grade I & III only. Transfer at least three portions of approx 0.1g each of the sample to smooth glass slides. Rub the material between glass slides determining the presence of grit by scratching noise and scratches on the glass slide.

4.3.4.2 Applicable to Grade II & IV only. Transfer the residue from silica dem to a smooth glass slide. Rub the material between glass slides and dem the presence of grit by scratching noise and scratches on the glass slide.

4.3.5 Determination of Acidity. Transfer a portion of approx 10g of the sample of a 250-ml beaker, add 100ml to neutral distd water and heat quickly to boiling while stirring. Filter immediately and cool to RT. Test the filtrate by adding two drops of phenolphthalein and then two drops of methyl red. If colorless to phenolphthalein and yellow to methyl red, acidity may be reported as none.

4.3.6 Determination of Free Sulfur. Extract an accurately weighed portion of approx 25g of sample with 50ml of the boiling ethyl ether for approx 15 mins. Filter, wash the residue with ether, and evaporate the combined filtrate and washing to dryness. To the ether sol residue add 10ml of concd nitric acid, 5ml of concd HCl and again evaporate the mixture to dryness. Moisten the residue with 2-4ml of concd HCl and then add 30-40ml of hot distd water. Filter, wash the residue with distd water, keeping the final volume of filtrate and washings within 100ml. Heat the filtrate to boiling and rapidly add 10ml of 5% barium chloride soln with vigorous agitation, and allow the barium sulfate ppt to settle for at least 24 hours. Filter thru a tared fine porosity crucible, wash the residue with hot distd water and test the last few washings of the ppt with 2 drops of silver nitrate to see that all chloride is removed. Ignite at dull red heat, cool in a desiccator and weigh. Calculate the increase in weight, corrected for the barium sulfate obsd in a blank dem on all reagents, to percentage of total sulfur in the specimen as follows:

\[
\text{Sulfur percent} = \frac{13.73 \times (A - B)}{W}
\]

where:

\[
A = \text{wt of ppt in sample}
\]
\[
B = \text{wt of ppt in blank}
\]
\[
W = \text{wt of specimen}
\]

4.3.7 Determination of Total Sulfur. Transfer an accurately weighed portion of approx 1g of the sample to a beaker. Add 30ml of concd nitric acid and 0.1g of the sample to a beaker. Add 30ml of concd nitric acid and 0.1 of sulfate-free sodium carbonate. Heat the mix to boiling and then add 60ml of concd HCl, slowly at first, until violent reaction has subsided. Evaporate the soln to dryness. Moisten the residue with 2 to 4ml of concd HCl, add 30-40ml of hot distd water and digest for a few mins on a steam bath. Filter the mix and wash the residue with distd water, keeping the final volume of filtrate washing within 100ml. Heat the filtrate to boiling and rapidly add 10ml of 5% barium chloride soln, with vigorous agitation. Allow the ppt of barium sulfate to settle for at least 24 hours. Filter the mix thru a tared fine porosity crucible, wash the residue with hot distd water and test the last few washings of the ppt with 2 drops of silver nitrate to see that all chloride is removed. Ignite at dull red heat, cool in the desiccator and weigh. Calculate the increase in weight, corrected for the barium sulfate obsd in a blank dem of all reagents, to percentage of total sulfur in the specimen as follows:
\[
\text{Sulfur percent} = \frac{13.73 (A - B)}{W}
\]

where:
- \(A\) = wt of ppt in sample
- \(B\) = wt of ppt in blank
- \(W\) = wt of specimen

4.3.8 Determination of Granulation. Place an accurately weighed portion of 25g of the sample and two metallic washers on the appropriate US standard sieve, in accordance with Specification RR-S-366, assembled to a bottom pan. Place a cover on the sieve and shake the assembly for 10 mins by hand or 5 mins by means of a mechanical shaker geared to produce 300 + 15 gyrations per min and 150 + 10 naps of the striker per min. When no more material passes thru, weigh the portion retained on the sieve and calculate the percentage of specimen passing thru the sieve as follows:

\[
\text{Percent thru} = \frac{W - (A - B)}{W} \times 100
\]

where:
- \(A\) = wt retained on designated sieve
- \(B\) = wt retained on sieves nested above designated sieve
- \(W\) = wt of specimen

5. PREPARATION AND DELIVERY. See Spec, p 6

6. NOTES. See Spec, pp 6 & 7

Graphite Determination in Propellants. When graphite is present alone, it can be detd by one of the procedures briefly described in Vol 2 of Encycl, p C57-R. It is essentially the same as that of MIL-STD-286A, Method 308.1.2. It is a gravimetric method using concd nitric acid as oxidizer. Parapillon et al (Refs 1 & 2) prefer using concd hydrogen peroxide in alkaline soln instead of nitric acid. They came to that conclusion after learning that Dra Ernst and Walter Berl decompd nitromethane by means of 30 hydrogen peroxide in alk soln. Parapillon & Rigel slightly modified the method of the Berls and applied it to det of graphite or carbon black in propellants. This method is described in Vol 2 of Encycl, p C58-R. The Parapillon method, in the opinion of Mr N. Liszt of Picatinny Arsenal, does not distinguish between carbon black and graphite and is not as useful. It is also more involved.

Mr Liszt sent (Ref 4) the procedure which, in his opinion, is probably the best general method for propellants and has the advantage of also determining carbon black if it is present. Method 308.1.2 of MIL-STD-286A has serious deficiencies and differences and must be changed in the future editions to conform with the following method 308.1.2 of X-PA-PD-1219, which was developed at PicArsn Determination of Graphite and Carbon Black by the Method Recommended by Mr N. Liszt of Picatinny Arsenal

1.1 Carbon Black Absent. Transfer a weighed portion of approx. 10g of the sample to a 400-ml beaker, add 75ml of approx 70% nitric acid, and heat the mix to a steam bath. When the reaction starts, remove the beaker and allow the reaction to proceed to completion. The rate of decomp can be controlled, if necessary, by adding a little distilled water from time to time. After evol of oxides of nitrogen ceases, heat the material if all the particles have not been completely decomposed. Cool the beaker and contents, and filter the soln thru a previously ignited Gooch crucible prepd with an adequate layer of asbestos which has been washed with 10 to 1 ml of approx 70% nitric acid and then with water. Wash the residue with hot water, remove the filtrate which contains nitric acid, (CAUTION: Do not mix acetone washings with nitric acid soln) and wash with acetone until all the organic material is dissolved as shown by the absence of coloration of the washings. Aspirate until the odor of acetone is no longer discernable. Dry the crucible and contents at 120–130°C for 1 hour, cool in a desiccator and weigh. Ignite the crucible and contents in a muffle furnace until all carbonaceous matter has been burned off, cool in a desiccator and weigh. Calculate the loss in weight of the crucible to percentage of graphite in the propellant on a total volatiles and added constituents-free basis.

1.2 Carbon Black Present. Proceed as directed in paragraph 1.1 to the point where the crucible and contents have been dried at 120–130°C cooled in a desiccator and weighed. The contents of the crucible represent the weight of the carbon black plus graphite. Place the crucible plus the carbonblack-graphite residue in a flat bottom, straight wall flask. Add 5ml
of 70% nitric acid to the crucible and 45ml of the acid to the flask. Connect the flask to a water cooled condenser and heat the contents of the flask to the boiling point by means of a hot-plate. Boil for 3 hours; allow the flask to cool, remove from condenser, remove the crucible, place in a crucible holder and filter the contents of the flask thru the crucible with strong suction. Wash the crucible and contents several times with distd water. Discard the filtrate and washings and continue to wash the residue in the crucible with water and acetone in order to remove all undissolved carbon black as may be determined by the absence of color in the washings and also the appearance of the remaining residue. Give several final washes with acetone; remove the crucible and place in an oven. Dry for 1 hour at a temp of 120–130°C. Remove, cool for 30 mins in a desiccator and weigh. Calculate the loss in weight from the previous weighing of the crucible plus residue to percentage of carbon black as follows:

\[
\text{Percentage of carbon black} = \frac{100A}{W}
\]

where:

\[A = \text{wt of crucible + carbon black residue loss of wt of crucible after 70% nitric acid boil.}\]
\[B = \text{wt of sample}\]

Place the crucible in a muffle furnace at a temp of 750–800°C and permit to remain until all carbonaceous matter has been ignited. Remove from furnace; cool for several mins in the atmosphere; place in a desiccator; cool further for 30 mins and weigh. Calculate the loss in weight to percentage of graphite as follows:

\[
\text{Percentage of graphite} = \frac{100A}{W}
\]

where:

\[A = \text{loss of wt of the crucible after ignition of 1 g}\]
\[W = \text{original wt of the sample}\]

A similar method for determination of graphite and carbon black is described in Std Methods of Chem Analysis (Ref 3) under the title “Carbon Black and Graphite, Gravimetric”. It is not included here because it is assumed that every chem lab has a copy of Std Methods

Refs: 1) M. Parpaillon, MP 34, 419–20 (1952)
2) M. Parpaillon & S. Rigal, MP 37, 305–17 (1955) & CA 50, 17451 (1956)
4) Nathan Liszt of Picatinny Arsenal; private communication (1974)

Graphite, Pyrolytic or Pyrographite. A dense graphite, stronger and more resistant to heat than ordinary graphite, and is used in rocket nozzles, missiles in general, and nuclear reactors. It can be prep'd by a recryst process from ordinary graphite. For this, forms of graphite are heated in a stream of a hydrocarbon gas. The C in the gas is deposited on the original form with the C crystals in alignment along the flat planes of the form. The pyrographite has a high tensile strength even at 5000°F. Sheets only 1 mil thick are impervious to liquids and gases. Its destruction temp is ca 6600°F


Graphitic Oxide (Graphitic Acid), \(C_2O_3(OH)_2\); mw 150.09; a solid substance of variable color ranging from green to brown, prep'd by treating graphite with strong oxidizing agents, such as nitric acid with K chloride or mixed acid (nitric + sulfuric acid) with K nitrate (Ref 2, p 828 & Ref 4, p 437). When oxidation with nitric acid is conducted in presence of a catalyst, such as vanadic acid or silver nitrate, the resulting product is mellitic acid (Ref 8)

Brodie (quoted in Refs 2 & 7) assigned the formula \(C_11H_4O_5\) to the first compd, but this has now been disproved. The compd was originally called "acid" because of the ease in which it dissolved in alkalies

More recently the product was investigated by K.A. Hofmann, U. Hofmann and others (Refs 3, 4, 5 & 6) and was assigned a very complicated structural formula (Ref 6, p 23 & Ref 7, p 459)

The product is now called "graphitic oxide" and has a varied compa with a ratio of carbon to oxygen of 2.9–3.5:1, and which can be approx distinguished by the color of the substance

Karrer (Ref 8, p 520) considers graphic
acid as an intermediate product obtd in oxidation of graphite to mellitic acid (Ref 8)

When heated, graphitic oxide decomp almost explosively (Ref 7)


**Graphitic Oxide By Explosion.** Carbon prepd by the expl of graphitic oxide has a different structure than any other form of C. Studies with the electron microscope and with X-rays and electron absorption indicate that it consists of very thin graphite layers which show the property of increasing specific resistance with increasing pressure. From data of the methylene blue adsorption and the catalytic activity in synthesizing HBr, it is concluded that the crystal faces are active rather than only the unsaid atoms in the edges of the faces

Ref: G.L. Ruess & F. Vogt, Monatsh 78, 222-42(1948) & CA 42, 7126h(1948)

**Graphitic Oxide Explosives.** Mixtures of "graphitic oxide" with MF, TNT, PA were patented for use in priming compns

Ref: A.W. Schorger, USP 1681259(1928) & CA 22, 3780(1928)

**Graphiting of Smokeless Propellants, also known as Glazing (qv).** French method, called plombinage or lissage is described by Pepin-Lehalleur (1935), p 306. Amer method is described in Davis (1943), p 306. The "sweetie barrel" used for tumbling propol grains with graphite is illustrated on p 291, Fig 71. This apparatus is also known as "tumbling barrel", "double-cone mixer" and "mushroom mixer" and is shown as Fig 3 on p D1558 of Vol 5 of Encycl

**Gravimetric Analysis, Inorganic.** That branch of quantitative chemical analysis in which a desired constituent is converted (usually by precipitation) to a pure compd or element of definite, known compn, and is weighed. In a few cases, a compd or element is formed which does not contain the constituent but bears a definite mathematical relationship to it. In either case, the amount of the desired constituent can be detd from the weight and compn of the precipitate. Methods exist for the detn of all the elements by gravimetric analysis

Gravimetric analyses of inorg expls and components of expl compns are described individually


**Gravimetric Analysis, Organic.** It concerns itself with carbon and hydrogen and various compds of these. Hydrocarbons, aldehydes and ketones, acids and derivatives, amines and related compds, sulfur-contg compds, phenols and derivs, and natural products such as cholesteral are analyzed using these methods. Many of the org compds contg nitrogen, such as azides, diazo, nitrites, nitrazes and nitro-compds, aliphatic and aromatic are expl and their analytical procedures are usually described individually. Many org compds contg peroxide group also are expl and their analyses are described individually


**Gravimetric Density or Apparent Specific Gravity.** See Vol 3 of Encycl, p D66, under DENSITY

**Gravimetric Density of a Propellant.** Addg to US OrdnProof Manual 7-26(1945), pp 31-2,
gravimetric density (gr d) represents a composite measurement of its relative bulk and flowing qualities. For its determination, the grains of propellant are allowed to flow through a restricted orifice of constant diameter ($\frac{1}{2}$ inch), under the pressure of a given head (or quantity of propellant) and to drop a distance of 7 inches into a measuring cup, which can hold 324.9 ± 0.1 ml of water at 20°C (which is equivalent to 5000 grains). On dividing the wt of propellant in the cup by the wt of water, the value of gr d is obtained. Because of the method of measurement used, the gr d is not related directly to sp gr. Thus, two propellants of the same sp gr but of different granulation, or having dissimilar surface conditions, would not flow nor pack the same, and as a result, would not have the same gr d.

In general, the gr d indicates the relative quantity of propellant that can be loaded into a cartridge case. Other things being considered equal, the higher the gr d, the greater the wt of propellant that can be charged into any given volume and, conversely, the lower the gr d, the lighter the wt of the charge.

Greaves and Hahn Explosives. BkPdr, Cordite or NG Explosives to which oxalates (such as ammonium) were added. They were introduced in 1895 in England, but it seems that Schöneweg had already proposed similar explos in 1886 in Germany.

Refs: 1) Daniel (1902), 357 2) Fedoroff & Clift 4 (1946), 41

GrBP (Ger abbr for Grobes Blättchenpulver). A large-flake, single-base, smokeless propellant used during WWI in German 150 and 210mm cannons.

Ref: Marshall 1 (1917), 303

Greek Fire. See under Black Powder in Vol 2, p B166-L. See also Fire, Greek in this Vol, p F31-L.


Green Cross (Grün Kreuz). A German term for lung-injurious agents used as offensive gases.

Ref: Wachtell (1944), 99

Greener (Poudre). Smokeless propellant based on NC, to which could be added NBz, graphite or carbon black. It was imported to England.

Ref: Daniel (1902), 357

Greener, William (1806–1869). British expert on guns who published in 1835 the book entitled "The Gun" and in 1841, "The Science of Gunnery", which, besides embodying the gun, dealt with cannon. He manufactured guns beginning in 1829 at Newcastle and then in 1844 transferred his business to Birmingham. He introduced many improvements in gunnery. Before his death in 1869 his business went to his son, known as W.W. Greener (1834–1921) who also became an expert in gunnery. He became known for improving and introducing the so-called "choke-bore", invented in 1874 in the

Ref: Daniel (1902), 357

Graydon Explosive. Mining expl prep'd by impregnating sheets of cotton or wool textile fabrics with NG and then placing them between two sheets of paraffined paper. The combined sheets were rolled into a solid cylinder with diam to fit the bore-hole, and then cut to the proper length.
USA. He published in 1881 the book: "The Gun and Its Development". The 9th enlarged edition (304pp), published in 1910, is in possession of authors of this Encycl. He has written since 1871 a total of seven books, some of which have reached nine editions. His books were translated into many foreign languages.

Greenhill, Sir George (1847–1927). A British ballistician who was the Director of the Ballistic Research Dept, Woolwich
Reference: A.D. Crow, MAF 7, 429–34 (1928)

Green Powder (French Anarchist’s Explosive). During the assaults conducted by these revolutionists, the following expl of the Chedire type was used in some bombs: KClO₃ 49, K₄Fe(CN)₆ 28 & Sugar 23. Due to its extreme sensitivity, the expl was dangerous to handle.
References: 1) Pérez Ara (1945), 222 2) Giua, Trattato 6(1) (1959), 396

Gregorini’s Explosive. AN 80, KNitraxe 5 & Al 15 to which was added 10% of a mixture of MNT 75, glycercine 5, Collodin 15 & K₂MnO₄ 5%

Gremuchaya Rust’ ili Ful’mintat Rusti. Russ for Mercuric Fulminate, which is still used in Russia for loading some blasting caps (See also under FULLINATES in Vol 6, pp F216ff
References: PATR 2145 (1955), p Rus S 2) Gorat (1957), 108 and (1972), 99

Gremuchii Studen’. Russ for Blasting Gelatin, contg NG 92 & NC 8%
Reference: Yaremchenko & Sverlov (1957), 183

Grenade. Ft for Grenade, such as Grenade à fusil: Rifle Grenade; - à main: Hand Grenade; - vomigène: Smoke Grenade; - fusante: Time Grenade; - incendiaire: Incendiary Grenade; - à manche: Stick Grenade; and - suffocante: Asphyxiating Grenade.
Reference: Patterson’s French-English Dictionary (1921), p 173

GRENADRES. A grenade is a small explosive or chemical missile, originally designed to be thrown by hand, but now also designed to be projected from special grenade launchers usually fitted either to rifles (or carbines) or guns ("Gun Grenades", Stielgranat in German).
History. While "rifle grenades" were not introduced until WW1, "hand grenades" existed as early as the 15th century. The first grenades were in the shape of a pomegranate and from this resemblance the name originated. By the middle of the 17th century, special military units were organized consisting of tall, strong soldiers called "Grenadiers", who could throw the grenades quite a distance. The grenades used at that time consisted of hollow cast iron balls (spheres) about 2½ inches in diameter, containing a charge of BkPdr and provided with a fuse or a slow match. Before throwing the grenade, the fuse was ignited and it took several seconds before the flame reached the charge of the grenade and exploded it.

Beginning with the middle of the 18th century, the grenade practically disappeared as a weapon, due to the great progress made at that time in small arms and cannons.

The special conditions prevailing at Port Arthur and at the battle of Mukden in the Russo-Japanese war (1904-1905) led to the revival of the hand grenade. A very successful grenade was invented by Capt Lischin. It was a cylindrical grenade charged with dry Guncotton and had a wooden handle attached for convenience in throwing. In Fig copied from Marshall 2 (1917), 566: A is an iron case, C–Guncotton with detonator, and D–a cup which could be removed to facilitate the insertion of detonator and could be turned so as to make the grenade either live or safe. As a further precaution the cap K was kept on until the grenade was used. In more recent Lischin’s bombs, the cap K was re-
placed by safety pin and TNT was used instead of Guncotton with an "exploder" between detonator and the charge. On impact, the pin O was driven into the detonator and fired it. The wooden handle B was ca. 18 inches long and had attached to it a tail of dome fabric to cause the grenade to travel nose first.

A simpler hand grenade was used by the Russians at the siege of Port Arthur. This improvised grenade was prepared by filling discarded cartridges with Ruck-a-rock [See PATR 2145 (1955), p R9-L.]

Accdg to Marshall 3 (1917), p 565, the Hale Handgrenade, also known as "policeman's truncheon" was similar to Lischin's. In its later model the container was of strong cast steel. Its HE charge was not specified.

During WWI the stabilization of the western front and the resort to trench warfare demonstrated the value of the grenade for close fighting, when used against personnel, obstructions, machine guns, nests, etc. The Germans developed three kinds of grenades: Stielhandgranate, Eisgranate, and Diskusgranate. The British developed a very successful Mills type grenade (see Fig from Marshall 2 (1917), p 566) which was egg-shaped. The French used a cylindrical grenade with a handle. The Americans used both the British and French grenades and did not bother to develop one of their own.

For filling grenades, any kind of HE can be used, provided it is fairly insensitive to shock. Dry NC was one of the first used. Other expls used were Ammonal, PA, Ceddite, etc. The USA also used a Grenite (qv) and another Nitrostarch expl congs NS 25, AN 34, binder 1 & Na nitrate 40%. These were later replaced by EC Blind Powder and finally by TNT.

As the range for grenades thrown by hand was rather low (maximum about 35 yards), attempts were made to increase it by using a sling or catapult and, of course, a greater range was attained. With the development of the rifle grenade, ranges up to several hundred yards have been reached. One of the original types of such grenades was Hale's Rifle Grenade. This and other grenades intended to be fired from rifles have a rod which goes down the rifle barrel and is fired by a special blank cartridge. A safety pin is removed before firing, but the grenade does not become "live" (armed) until it has travelled some distance, when the striker, which hits the detonator on impact, is released by the rotating motion imparted to the grenade by the vanes attached to it.

Since WWI there has been considerable development and standardization of grenades. They may be divided into fragmentation, demolition or offensive, antitank, smoke, illuminating, chemical and practice grenades.

In modern warfare, such as of WWII, the grenade, especially the rifle grenade, has become a diversified weapon. It started to be used not only as an antipersonnel weapon and against machine gun nests, but also against...
tanks and armored vehicles, booby traps etc. In addition, it has been used for demolition, for incendiary effect, as smoke producers and for signalling. Progress in grenade design has included greater penetration and larger number of fragments. As fillers, TNT, Pentolite and RDX expls, such as Cyclotol, have been used.

Descriptions of grenades used by the US Armed Forces during WWII are given in the book of Maj O'hart (1946), p 354-62. Many of these types of grenades are still in use at the present time (see further).


As previously mentioned, there are two types of grenades — hand and rifle. They may be described as follows:

Hand Grenade, as the name implies, is intended primarily to be thrown by the individual soldier. All standard US Army hand grenades have a delay-type fuze except for Grenade M26A2 with fuze M217 which has an impact-delay-type fuze (see Fig 1). Classification accdg to service uses, tactical uses, particular filler and to the time of functioning is given below. Besides their use against the personnel, vehicles (like tanks), and demolition, they can be used for clearing passages thru mine fields.

Hand Grenades are kept safe in handling by the safety pin that holds the lever in place, thus restraining a striker under the lever. The lever is grasped by the hand used for throwing, and the safety pin is removed. When the grenade is thrown, the lever flies off, allowing the striker to rotate by spring action and strike the primer. This ignites the delay element of 4-5 secs, after which the grenade functions.

Rifle Grenades are designed for projection from a grenade launcher attached to the muzzle of a rifle (see Fig 2). They are used against
FIG 2 HEAT Rifle Grenade M31
amored targets, against personnel, for screening, signalling, or for incendiary effect. Like hand grenades, they are kept safe in handling by a safety pin which is removed after the grenade is placed on the launcher and before firing the rifle.

Present US hand and rifle grenades can be classified according to their service use as follows:
- **Fragmentation Grenades**, which contain a HE chge in a metallic body, the fragments of which do most of the damage. The thrower must take cover and cannot continue advancing until a safe time after the detonation. Their effective fragment range is greater than the distance they can be thrown.
- **Offensive Grenades** contain a HE chge in a paper body or other thin container and do most of their damage by blast effect, resulting in demolition and lethal shock, rather than by fragmentation. The thrower can, therefore, continue to advance after throwing the grenade which accounts for the name. Their effective fragmentation range is safely less than the distance they can be thrown.
- **Practice Grenades** contain a small BkPdr spotting chge to give an indicating puff in practicing with grenades.
- **Training or Dummy Grenades** are totally inert and are intended for practice throwing.

Note: Accdg to the late A.B. Schilling of PicArsn, Offensive Grenades are designed for use in attack and are so designed as to not impede the advance of the attacker, eg, Base-ball Grenade.

Defensive Grenades (usually of the fragmentation type) are used where cover is provided or must be taken by the thrower; eg, Pineapple Grenade.

Offensive-Defensive Grenades are so designed that, by the addition of a sleeve or similar device, the offensive design may be used as a defensive type by a fragmentation producing effect.

Grenades may also be classified according to tactical use or according to the particular filler, as follows:
- **High-Explosive Grenades** contain HE for fragmentation or blast effect, the expl being TNT, Tetrytol, Pentolite, Cyclonite etc.
- **Chemical Grenades** contain a special mixture for Chemical Warfare (CW). The special type of filling in common use is HCl smoke mixt, and such grenades are known as smoke grenades. The smoke mixt may be colored for signalling purposes.
- **Illuminating Grenades** contain mixts producing strong light for illuminating terrain (Comp with Flares).
- **Incendiary Grenades** contain an incendiary mixt for starting fires.

Grenades may also be classified according to the time of functioning, as follows:
- **Automatic Time Grenades** contg a fixed delay that is set off automatically when the grenade is thrown or fired from a rifle launcher.
- **Contact Grenades** contg no delay but which function when the grenade hits a target at any distance within range of throwing or launching.

Present US Grenades are described in TM 9-1330-200 (1971) entitled "Grenades, Hand and Rifle", Departments of the Army and the Navy, Washington, DC.

Hand grenades are of various types which include fragmentation, illumination, chemical & practice. They are of such a size & shape as to be convenient for throwing by hand. Hand grenades are used to supplement small arms against an enemy in close combat, against a variety of combat targets, for riot control, incendiary purposes & training. The five basic types of hand grenades are as follows:
- **Fragmentation**. Used to produce casualties by high velocity projection of fragments.
- **Illuminating**. Used to provide illumination of terrain & targets.
- **Chemical**. Used for riot control, incendiary, smoke screening, smoke signalling & incapacitating purposes.
- **Offensive**. Used for their blast effect.
- **Practice & Training**. Used for training personnel in use, care & handling of service grenades.

The expls used in fragmentation grenades may be either Comp B or TNT (flaked or granular); illuminating grenades use a pyrotechnic compn; chemical agents CN & CS (See Vol 2, p C167-L) are used in riot grenades; smoke grenades use HCl filler (See Vol 2, p C168-L) or SP filler (See Vol 2, p C169-L) or red, green, yellow or violet smoke compn; incendiary grenades use Thermite & an igniter mixt; TNT (flaked) is used in offensive grenades; and no expl filler is used in practice grenades.
Rifle grenades, as the name implies, are fired from a rifle. They may be fired at low angles or high angles, depending on the type of grenade & effect desired. All grenades are stabilized by the use of fins at the rear section. Rifle grenades are used against armored targets, against personnel, for screening or signalling, or as incendiaries against flammable targets. There are three general types of rifle grenades:

Antitank. Used against armored targets or fortification. It contains a Comp B shaped chge capable of penetrating 10 inches of armor plate or 20 inches of reinforced concrete at an effective range of 115 meters Chemical. There are four basic kinds: WP smoke, HC & colored smoke, incendiary, and smoke streamer. All are used primarily to produce smoke either for signalling or screening effects. The WP smoke also has incendiary capabilities. The smoke grenade & smoke streamer use a chge of baking soda, K chlorate, sugar and a dye to produce green, red, yellow or yellow colored smoke

Practice. These grenades use no HE chge. They are used for training personnel in the care, handling & use of rifle grenades prior to training with service grenades. One type is issued ready for use; other types are assembled from practice & training hand grenades and grenade projection adapters

With a grenade projection adapter, a hand grenade can be converted into a rifle grenade. The adapter consists of a stabilizer tube with a fin assembly on one end and gripping claws on the other end

Addnl Refs for Grenades:
E) "Small Arms Material and Associated Equipment", TM9-2200 (1949)
F) J.H. Frazer et al, USP 2504119 (1950) & CA 44, 6130 (1950) (Use of hand grenade to clear land mines after spraying field with a mix of perchloric acid & ethylene glycol monoethyl ether)
H) R.C. Schofield, PA Memo Rept 153 (1958) (Examination and Evaluation of Grenade, Hand, Fragmentation, Mod (?), and Fuze, Experimental
I) A. Langhans, Soldat und Technik 1961, 192; Explosivst 10, 227 (1962) (Ein neues Granatengewehr)
K) H. Schmolzmann, Auslegeschrift 1155694 (1963); Explosivst 12, 73 (1964) (Handgranate, die als Gewehrgranate verwendbar ist)
O) R. Bigelow, Newark News Magazine (8 Oct 1967)
R) US Military Specifications:
Grenade Launcher, M7A3, MIL-L-1225B (Nov 1957)
Grenade Launcher, M76, MIL-L-45528A (March 1965)
Grenade Launcher, 40mm, M79, MIL-L-45589 (Feb 1970)
Grenade Launcher, 40mm, XM129, MIL-L-45922 (March 1971)
Grenade Launcher, 40mm, Detachable, M203, MIL-L-45939 (Sept 1971)

Grenade Launcher. A device which functions as an extension of the barrel of a rifle which permits firing of rifle grenades. The launcher is secured to the muzzle of a rifle by means of a clip latch which fits over the bayonet stud.
Fig 3 is an illustration of the Grenade Launcher M7A3. The M79 Grenade Launcher is a 40mm tube with firing mechanism which can send a grenade as far as 400 meters. Besides HE grenades, it can launch illuminating, smoke and signalling missiles. Developed at PicArsn and used successfully in Vietnam War (Addnl, Ref Q)

Cartridges for propelling rifle grenades are briefly described in Vol 2 of Encycl, p C74-R, item c) and illustrated on p C75. More detailed description is given in "Small Arms Ammunition", TM 9-1305-200(1961), pp 50–1

Grenades, Special Topics and Testing.

Lots. Grenades are divided into lots of various sizes

Packing. Grenades should be packed separately from bouchons and firing mechanism, each in a separate wooden box or in a separate compartment of the same box. The exception is in the case of grenades loaded with EC Blank Fire Powder which can be packed with firing mechanism assembled

Maintenance and Surveillance. Similar to the regulations outlined under "Trench Mortar Ammunition"

Renovation and Salvage. Similar to regulations outlined under "Trench Mortar Ammunition", with the exception that bouchons and firing mechanisms are not renovated or salvaged unless directed by the proper authority

Destruction. For offensive hand grenades and rifle grenades, not more than 40 grenades shall be packed in close contact with each other in a box and the ensemble placed in a pit, about 4 ft deep, free from stones or other debris that may form missiles. On top of the pile and in intimate contact are placed several ½ lb TNT blocks, using 1 block for each 6 grenades. One of the blocks in the pile is fitted with a No 8 electric blasting cap, to which is attached several feet of BlkPdr safety fuse. A lid should be placed over the box (taking care that the safety fuse is not pinched) and the box should be covered with 3–4 ft of earth or other suitable material

If only a limited quantity of grenades have to be destroyed, it may be done by burning. For this, a pit similar to that used for above-mentioned grenades, is provided with a heavy metal cover to stop flying fragments and unexploded grenades. A fairly thick layer of flammable material, such as wood or coke, is placed under the pile of grenades and, as soon as the fire is started, the cover is placed over the pit and all persons retire behind a barricade.

For destruction of "fragmentation" grenades, the following method may be used:

After unscrewing the fuze from the body of the grenade, the EC Blank Fire Powder is emptied into a barrel of water and the fuze is destroyed by the "pit and chure" method, as described under "Metal Components, Destruction". The EC Blank Powder may later be spread out on the ground, allowed to dry and burned, as described under Black Powder

If fuzes cannot be disassembled easily, the grenades should be destroyed with demolition block in the same manner as offensive and rifle grenades

Safety Precautions. Grenades and bouchons should never be dropped, thrown or subjected to rough handling. No tampering should be allowed, as many accidents have been due to this cause
Testing of Grenades. For hand grenades, the test consists in projecting them from a pneumatic "grenade thrower" (which removes the safety pin from the fuze simultaneously with the opening of the air valve of the grenade propelling apparatus) and making the following observations:

a) The time from the instant of propelling until detonation
b) The order of functioning
c) The promptness of the release of the handle

For rifle grenades, the test is conducted essentially in the same manner, with the exception that the grenade is fired from a rifle instead of being propelled from a pneumatic grenade thrower. The "antitank grenades" are usually fired against an armor plate.

All personnel must be under cover during testing of hand & rifle grenades.


Grenadine (or Granatina). Mining explosive patented in 1882 by Sala and which contained K nitrate, sulfur, benzene, glycerin, ashes and sand.

Refs: 1) Daniel (1902), 361 2) Fedoroff & Clift (1964), 4

Grenadine. Mining explosive patented in 1883 by Gacq: K nitrate 69, sulfur 19, ashes and tannin mixed with water 12.

Ref: Daniel (1902), 361

Grenage. Fr for Graining

Grenée Poudre. French smokeless propellant manufactured at Moulin Plank: NC 60, Ba nitrate 30, K nitrate 6, Gellose (agar-agar) 3, paraffin 1%

Refs: 1) Daniel (1902), 381 2) A. Pérez Am (1945), 440 (Pólvora Grenée)

Grenite (Amer). A NS expl of varied compn: NS 95.50–98.25, petroleum oil 0.75–2.00, gum arabic 0.75–2.00, moisture 0 to 1.00%. Was used during WWI in hand grenades. Its explosive properties have been experimentally determined. See also Vol 5, under DYNAMITE, class X, item (d), p D1611–L

Refs: 1) Davis (1943), 275–76 2) A. LeRoux, MP 33, 211–21 (1951) & CA 47, 10229 (1953)

Gribeauval, Jean-Baptiste de (1715–1789), French General who completely revolutionized artillery. His career contributed so much to Napoleonic victories.


Griscellite-couche or Lignamite-couche (Fr). Permissible expl in NG 12.0, CC 0.5, AN 86.0 & cellulose 1.5%.

Ref: Vennin, Bédot & Lécorché (1932), 554

Griess, Peter (1829–1888). German chemist, discoverer of the diazotization reactions which are of very great importance in the dye industry. These reactions serve also in the prep of some expls, as for example Diazodinitrophenol (DNApN), described in Vol 2 of Encycl, p B59–L as Dinitrobenzenediazoxida. Its tests are given in Vol 5, pp D1160–R to D1163–L.


Griffing's Explosives. 1) Granulated mix of sugar 25, K chlorate 30, powdered charcoal 15, powdered MnO2 15, milk sugar 5 & Zn flue dust 10% (Ref 1) 2) KCIO3 50, sugar 49, KMnO4 0.34, S 0.33 & talcum powder 0.33% claimed to be suitable as Gunpowder (Ref 2)

Refs: 1) C.E. Griffing, USP 991057 (1911) & CA 5, 2332 (1911) 2) C.E. Griffing, USP 1282413 (1918) & CA 13, 187 (1919)


Grignard’s Reaction and Reagent. Grignard’s reaction, also known as magnesium alkyl condensation, serves for introducing by means of G’s reagent of a carbon atom into the hydrocarbon radical of a complex. It offers a ready means of passing from a lower member of a homologous series to a higher member. Grignard’s reagent is any of a group of organic magnesium compounds of the general type RMgX, where R is an organ radical and X is a halogen (usually iodine).


Grignon. Spanish for the residuum left after pressing the oil from olives. When distilled it yields ca 4% Ca acetate and 1.2% of crude wood alcohol.

Note: If the distn does not go to carbonization the residue is a cellulose and there is no reason why it cannot be nitrated to produce NC. If the residue is carbonized, the resulting product should be suitable as an ingredient of expls in lieu of charcoal. This, of course, concerns only the countries with large production and consumption of olives and short supply of cellulotic materials (like Spain or Italy).


Grinding. See under Crushing and Grinding in Vol 3, p C564-R.

Grisou. French for Firedamp.

Grisou-dynamites are French Dynamites (Explosives containing NG) safe for use in coal mines. See Vol 1, p A467-L, under Antigrisou (Explosifs). They may be subdivided into two classes:

Grisou couche: Dynamites for use in coal seams; according to French Regulation, they should have a temp of expl below 1500°. Following are examples:

a) NG 12.0, Colloid Cotton 0.5 & AN 87.5%.

Temp of expl <1500°. Lead block expansion 245cc, Lead block crushing 8.5mm.

b) NG 12.0, Colloid Cotton 0.5, AN 82.5, KNitrate 50%.

Temp of expl <1500°. Lead block expansion 235cc, Lead block crushing 7.5mm.

c) NG 16, EGDN 4, Colloid Cotton 0.5, AN 55, Cellulose 2.5, NaCl 22%. This expl is also called Chlorurée n°1.

Grisou roche: Dynamites for use in rock surrounding coal seams; they should have a temp of expl below 1900°.

a) NG 29.4, Colloid Cotton 0.6 & AN 70%.

Temp of expl <1900°. Lead block expansion 295cc, Lead block crushing 18mm.

b) NG 29.4, Colloid Cotton 0.6, AN 65 & KNitrate 5%.

Temp of expl <1900°. Lead block expansion 285cc, Lead block crushing 18mm.

Note: The addition of 5% KNitrate instead of the same quantity of AN was found to increase the safety, probably because the KNitrate fomed on expl dissociate at high temps thus absorbing part of the energy and lowering the overall temp.

Grisou-dynamite chlorurées n° 1, n° 14 and n° 15 are in Vol 3, pp C450 & C451.

Grisou-naphthalites. Fr coal-mining expls consg Nitronaphthalenes instead of NG. There are two classes:

a) Grisou-naphthalite couche: TNN 5.0 & AN 95%.

b) Grisou-naphthalite couche salpétérée: TNN 5, AN 90 & K nitrate 5%.

c) Grisou-naphthalite roche: DNN 8.5 & AN 91.5%.

d) Grisou-naphthalite roche salpétérée: DNN 8.5.
AN 86.5 & K nitrate 5%  

Grisou-tétrylite-couche. Fr permissible expl:  
AN 88, K nitrate 5 & Tetryl 7%  

*Refs:*  
1) Naoum, NG (1928), 432, 433  
2) Marshall 3(1932), 121  
3) Pepin Lehalleur (1935), 353  
4) Davis (1943), 350

Grisounines. According to Gody (Ref), they were Favier type expls manufd by the Société Française des Poudres de Sûreté:  
Grisounine roche: AN 91.5-92.0 & DNN 8.5%  
Grisounine couche: AN 95.5 & TNN 4.5%  

*Note:* The same expls are called by Gody on p 705 Grisoutines  

*Ref:* Gody (1907), 594

Grisonites. Favier type expls, safe for use in gaseous coal mines. They are permissible Ammonium Nitrate expls which contain an aromatic nitrocompd in place of NG (See Antigrisou Favier under Antigrisou (Explosifs) (Vol 1, p A467-L). These expls are identical with Grisou-naphthalites and Grisou-tétralite described above. They can be prepared by grinding the ingredients together in a wheel-milo (meule, in Fr), followed by sifting and packing in paraffined paper cartridges  

Grisounite gomme. Accord to Daniel (Ref 1, p 296), it was a mining expl contg AN 70 & NG 29.5, gelatinized with 0.5% Collod Cotton, Accord to Naoum (Ref 6, p 404), it consisted of AN 80, NG 19.6 & Collod Cotton 0.4%  

Grisounite N 4c. Fr mining expl contg AN 87.4 & DNN 12.6% with detonvel 3635m/sec when compressed and 4100m/sec in powder form (Ref 4, p 493)  

Grisounite N 4. Fr mining expl contg AN 15, Na nitrate 58 & TNN 27% with deton vel 3800 m/sec at d 1.38 or 3200m/sec at d 1.32 (Ref 4, p 493)  

Grisounite-rocche. Fr nonpermissible expl contg AN 92 & DNN 8%. It is list here under Grisounines. Another Grisounite roche contd AN 70, NG 29.4 & Collod Cotton 0.6%. A similar expl contg AN 70, NG 29 & Collod Cotton 1% is called by Davis (Ref 8, p 351) Grisou-dynamite roche  

Grisounite-talite ou Grisoutolite. French expl contg TNT instead of TNN. For example, Grisoutolite-couche contd TNT 6.5, AN 88.5 & K nitrate 5.0% (Ref 6, p 433)  

*Refs:*  
1) Daniel (1902), 296 & 362  
2) Gody (1907), 594  
3) Marshall 1(1917), 388, 389, 395  
4) Marshall 2(1917), 493  
5) Colver (1918), 250, 275, 276, 494, 636  
6) Naoum, NG (1928), 384, 403, 303, 432, 433, 445  
7) Pepin Lehalleur (1935), 343, 352-3  
8) Davis (1943), 350-31  
9) Clift & Fedoroff 2(1943), G5 10 PATR 2700, Vol 1(1960), p 4A66-R

Grisoutina C; Grisoutina al 10% and Grisoutina al 13.20%. See Vol 3 of Encycl, p C451-R, under Italian Permissible Explosives

Grisoutines (Belgian & French). Blasting expls of which Gody (Ref 1) lists the following Belg comps:  

*Grisoutine I:* NG 24.0, CC 1.0 & AN 75.0% (Ref 1, p 713)  

*Grisoutine II (d’Arendonck):* NG 44.0, NaN 10H2O 44.0 & woodflour 12.0% (Ref 1, p 714)  

Gody also lists the following French comps:  

*Grisoutine d’Abion dite B:* NG 11.76, CC 0.34 & AN 88.0% (Ref 1, p 378)  

*Grisoutine A (Cugny):* NG 4.35, CC 0.15, resin 4.55 & AN 90.45% (Ref 1, p 376)  

*Grisoutine B (Cugny):* NG 5.875, CC 0.125 & AN 94.00% (Ref 1, p 376)  

*Grisoutine C (Cugny):* NG 11.75, CC 0.25 & AN 88.0% (Ref 1, p 376)  

*Grisoutine D (Cugny):* NG 19.50, CC 0.50 & AN 80.0% (Ref 1, p 376)  

*Grisoutine M (Société générale pour la fabrication des dynamites):* AN 80 & Gührodynamite of 75% NG 20% (Ref 1, p 359)  

*Grisoutine B (Paulilles):* NG 11.76, CC 0.24 & AN 88.00% (Ref 1, p 705)  

*Grisoutine F (Paulilles):* NG 19.6, CC 0.4 & AN 80.0% (Ref 1, p 705)  

*Grisoutine-gomme (Paulilles):* NG 29.10, CC 0.9 & AN 70.0% (Ref 1, p 705)  

*Grisoutine No 2 (Paulilles):* NG 35.0, cellulose 13.0 & Na nitrate 52.0% (Ref 1, p 705)  

*Grisoutine No 3 (Paulilles):* NG 22.0, charcoal 12.0 & Na nitrate 65.0% (Ref 1, p 705)  

Dauatrice (Ref 2), as quoted from Ref 3, gave for French Grisoutines: NG 11.8 to 29.1, CC 0.2 to 0.9, AN 83.0 to 65.0 & Na nitrate 5%  

*Refs:*  
1) Gody (1907), 359, 376-78, 705 &
Grisoutites (Belg). Permissible expls manufd at Matagne-la-Grande, such as NG 42 to 45, kieselguhr 11 to 12 & MgSO₄.7H₂O 47 to 43% (Ref 1, p 358). Another cmpn is given on p 701 and in Ref 2: NG 44, cellulose 12 & MgSO₄.7H₂O 44%
Refs: 1) Gody (1907), 358 & 701 2) Clift & Fedoroff (1943), p G5
Grisou-tolite-couche. See Grisounite-tolite, under Grisounites
Grist is one of the names for size (fineness) of ground particles. Accdg to Marshall (Ref), the size of particles is of great importance in the expls industry. For instance, in the case of BkPdr, which contains no ingredient which is itself explosive, it is of great importance to grind the ingredients very fine and to mix them intimately. In the case of mixts contg at least one substance which is an expl, coarser grinding and rougher mixing may suffice
Sometimes, as in the case of Permissible Explosives, it is undesirable to grind the ingredients too fine, as such grinding increases the density of the product and seems to increase the tendency to ignite firedamp when the expl is fired
Too fine grinding is also undesirable in expls contg a comparatively small amount of liquid expls, such as NG. It has been observed in such cases that they are much easier to detonate if the liquid is not absorbed completely by the non-explosive ingredients (dope), but some free microscopic liquid particles are left imbedded between the particles of dope. Such droplets of liquid serve as initiating centers. For this reason, in expls contg small amounts of NG, it is not advisable to use absorbents (such as wood pulp) which are ground too fine.
Particle size affects greatly the rate of detonation of solid expls. In general, the smaller the size, the higher the rate of detonation
Ref: Marshall 2 (1917), 372
Grisunofoitita. See under Spanish Permissible Explosives in Vol 3, p C455-L
Grisutin. Russ expl consisting of NG gelatinized with Collodion Cotton 12–30 & AN 88–70%, with added absorbent such as sawdust (Ref 1). Accdg to J.E. Capell & A.B. Shilling of PicArsn (quoted from Ref 2) some cartridges 6 inches long and 1 to 1½ inches in diam, marked "Grisutin" were probably used for military purposes. Their cmpn was not detd at PicArsn
Grisutita copa and Grisutita roca. See under Spanish Permissible Explosives in Vol 3, p C455-L
Grit. Fine stony or hard particles, such as sand, pieces of rock or metal, usually with rough surface
Grit Influence on Initiation of Explosives by Impact and Friction.
High speed cameras reveal that initiation of expln in liquid and many of the solid expls, begins at "hot spots", generated either by the adiabatic compression of a gas pocket or by friction on a particle of grit, which creates the hot spot.
According to Copp et al (Ref 1), sensitivity to impact of PETN and other HE's is increased if grit of hardness greater than 4 on the Moh's scale is present. Bowden and Gurton (Refs 2, 3 & 4) claim that hardness over the range 2 to 7 is relatively of not so much importance as the mp of the grit. It has been claimed that only grits melting above 400° or even 430° increase the sensitiveness to impact of such expls as PETN, and that grits with mp of 500° and higher are necessary to cause increased sensitivity to LA, LS and MF
Groggins, Philip H. American chemist, graduate of College of the City of New York (1912). Spent first 9 yrs with duPont at Gibbstown, NJ then moved from plant to plant for varied experiences. In 1935, he published the first edition of his monumental work “Unit Processes in Organic Synthesis”. His first book was “Aniline and Its Derivatives” Ref: Anon, C&EN 27, 2423, 2457 (1949) & CA 43, 7275 (1949)

Grommets. The term grommet as used in Ordnance means a ring formed of rope, wire, plastic material etc laid around rotating bands of projectiles shipped without packing. As rotating bands are made of softer metals than a projectile itself, they need extra protection which is achieved by using grommets

The simplest grommet consists of a piece of rope, looped at each end and wrapped once directly over the rotating band or in front of it, or in case of double-banded shell, between the bands. After this the hemp twine is drawn tightly thru the two end loops and secured by a “slipknot” (Knot designed to slide or pull free under strain) Ref: US War Dept Tech Manual TM 9–1901 (1950), pp 382–85

Grombovy (Thunderer) (Russ). A powerful expl proposed in 1886 by I.M. Cheł'tvov: AN 72.5 & Anm Pricate 27.5% for loading artillery projs and Naval mines Refs: 1) Yaremenko & Svetlov (1957), p 5
2) Gorst. (1957), 13

Grove Diameter of a rifled weapon is measured from the bottom of one groove to the bottom of that opposite or, in case an odd number of these are employed, calculated as equalizing the diam of the bore (See “Bore Diameter” in Vol 2 of Encycl, p B248-R) plus twice the depth of one groove, since in this instance these are so distributed that no one ever directly faces another Ref: Hayes (1938), 194

Grottanelli Stability Test. A 500g sample of proplnt as delivered (previously undried) is heated at 80° in a special glass reaction tube, while 0.05 liter of air, saturated with moisture, is passed thru it and then into bubbler tubes contg distd water. The acidity of the water in the bubbler tubes is measured periodically with a pH meter, without removing the sample, and the heating continued for as many days as required to reach a pH of about 1.0. At this stage, the proplnt is considered dangerous and the heating is discontinued

Pavlik (Ref 2) used a method which might be considered as a modification of both, Grottanelli’s and Hansen’s methods. In this test, the pH was measured potentiometrically using a quinhydride electrode.

Déribé (Ref 3) modified these methods by adding the water, used for washing the gases evolved during the stabilization test, directly to the container in which the propellant had been heated and determining the pH colorimetrically (instead of electrometerically) by a series of sensitive indicators (thymol blue for pH 2 to 3.3; bromophenol blue 2.8 to 4.6; bromoresol green 3.6 to 4.8; methyl orange 3.8 to 5.2; bromocresol purple 5.2 to 6.8 and bromothymol blue 6.0 to 7.6)


Ground Coke. The material prepd by finely grinding coke. Such material was used in primer compus such as MF 5, K chlorate 9, Sb₂S₃ 3, Tetryl 2 & ground coke 1 part. It was also used in commercial expls, such as Black Dynamite, Dahmenire and Golovine Explosive, listed on p C292-L in Vol 3 of Encycl, under Coke
Ground Glass for Use in Primer Compositions. See under Glass.

Grounding Against Lightning in Explosives and Ammunition Plants is described in
Refs: 1) R.’ Rinkel, SS 6, 141-45 (1911) (Ueber den Blitzschutz von Sprengstoff-Fabriken)

Note: An interesting recent grounding method is employed in the Fábrica Naval de Explosivos at Azul, Argentina

Ground Signal Propellant. Its compn consisted of NC (13.25% N) 91.25, NG 5.5, DPHA 0.75, K nitrate 0.50, graphite 0.50 & Ba nitrate 1.50%. It was used in the form of a cross
Ref: Armament Engineering (1954), p 43

Growth of Explosion in Electrically Initiated RDX. It was studied both in powdered RDX initiated by a bursting bridgewire and in pressed RDX initiated by passing current thru a column of RDX-graphite mixt incorporated in the charge. In the former case, a reaction wave moves out from the bridgewire at a velocity characteristic of low-order deton, with a transition to high-order deton occurring at a reproducible induction distance which depends only weakly on the stored elec energy. Induction distances from 9.5mm to 17.5mm were observed, depending on geometry and loading d. Interctions of 2 pre-high order waves were investigated as well as the ability of such waves to cause deton in Comp B. In contrast, growth of expln in the pressed RDX appears to be governed, at least initially, by thermal mechanisms; delays of more than 1 msec have been observed between the discharge of the elec energy and substantial expln of the charge

Grüne proposed in 1887 Dynamites contg as absorbents: charcoal mixed with kieselguhr, or kieselguhr alone previously heated to incandescence in the absence of air, and then cooled. It was claimed that such Dynamites do not exude NG even when brought in contact with water
Ref: Daniel (1902), 365

Grüneisen Equation of State is described in Vol 4 of Encycl, p D278-L and Mie-Grüneisen Equation of State is on pp D289-L & R and p D290-L

Grüneisen Function, Effective is defined by Anderson et al (Ref) as “the ratio of the thermal pressure difference to the thermal energy density difference at a given volume”. Values of the effective Grüneisen function are found to be in the range 1.4 to 2.2 and tend to decrease with decreasing volume and increasing temp (Compare with Grüneisen Parameter, which is described under “Detonation, Equations of State”: “Mie-Grüneisen Equation of State” in Vol 4, p D289-L)

GSX. Code name for 1,7-Dichloro-2,4,6-trinitro-2,4,6-triazahexane described in Vol 5 of Encycl, p D1215-R

GTNB. Abbr for Glycol-di-trinitrobutyrate. See Ethyleneglycol-di-trinitrobutyrate in Vol 6, p E255-R

Gu. Our abbr for Guanidine

Guaiacol and Derivatives
(Guaiacol, Methylcatechol or o-methoxyphenol (Guaiacol or Benzacetochinmonomethyläther in Ger), HO.C6H4.OCH3; mw 124.13, prisms, sp gr 1.143 at 15/15°, mp 28.3°, bp 207°; sl sol in w; sol in org solvts. Prepd by heating catechol, alkali, and sodium methyl sulfate)
at 175°. Forms an exp! pircate, om-red ndls, mp 80° (86°, 90°)
Refs: 1) Beil 6, 768,(382), [776] & [4200]
2) E.V. Goupr-Vesanez, Ann 147, 248 (1868)
4) Sax (1968), 801-L
Azido, C₂H₃N₃O₂, and Diazido, C₂H₆N₆O₂, derivs were not found in Beil

Mononitroguaiacols, HO.C₆H₃(NO₂)₂OC₂H₅; mw 169.13, N 8.28%. Four derivs are known:
3-Nitroguaiacol, yel ndls (subl), mp 62°; sol in w, steam distils. Prepd by nitration of
guaiacol in HAc at RT
Refs: 1) Beil 6, 788, (391), [789] & [4264]
2) H. Kaufmann & W. Franck, Ber 39, 2725 (1906)

4-Nitroguaiacol, yel ndls (w), mp 104°. First prepd by saponification of the acetate, which
had been prepd by nitration of guaiacolacetate in fuming nitric acid. Sodium salt, om-red
ndls, bums explosively in a flame
Refs: 1) Beil 6, 788, (391), [789] & [4264]
2) H. Kaufmann & W. Franck, Ber 39, 2725 (1906)

5-Nitroguaiacol, yel ndls (w), mp 99-100° (103-4°); sol in alc, eth & boiling w. Prepd by
oxidation of 2-methoxybenzoquinone-1,4-oxime-4 with alkaline ferricyanide
Refs: 1) Beil 6, 788, (391) & [790]
2) H. Rupe, Ber 30, 2446 (1897)

6-Nitroguaiacol, yel prisms or rhmb, mp 68.5-69.5°; sol in most org solvents except
CCl₄, CS₂ & petr eth; insol in w. Prepd by saponification of the corresponding acetate
Refs: 1) Beil 6, [789]

3,5-Dinitroguaiacol, yel plts or ndls (dil alc), mp 121-3°; sol in warm dil alc. Prepd from
guaiacol in eth at 0° by adding nitrogen oxides from arsenic trioxide & nitric acid
Refs: 1) Beil 6, 791, (394), [794] & [4273]
2) J. Herzig, Monatsh 3, 825 (1882)

3,6-Dinitroguaiacol, yel prisms (petr eth), mp 69-70°; sol in cold org solvents. Prepd from
3-nitrocatechol-2-methylether in cold HAc by adding nitric acid
Refs: 1) Beil 6, [794]

4,6-Dinitroguaiacol, yel ndls (CS₂), mp 80°; sol in alc & EtAc; sl sol in benz, chlf & CS₂.
Prepd by heating carbonic acid di(3,5-dinitro-2-methoxyphenylester) with aq-alc sodium carbonat
Refs: 1) Beil 6, [394]
2) F. Pollecoff & R. Robinson, JChemSoc 113, 649 (1918) & CA 12, 2314 (1918)

5,6-Dinitroguaiacol, plates (CCl₄), mp 109.5-110°; sol in most org solvents except CCl₄, CS₂ &
petr eth; dil sol in cold w. Prepd from 3-nitrocatechol-2-methyl ether in cold HAc by
adding nitric acid
Refs: 1) Beil 6, [793]

Trinitroguaiacols, HO.C₆H(NO₂)₃OC₂H₅; mw 259.09, N 16.22%, OB to CO₂ -52.5%
3,4,5-Trinitroguaiacol, yel prisms (w) or ndls (chlfr-petr eth), dec 144-7°; sol in w, alc &
eth. Prepd by boiling an HAc soln of the corresponding dimethyl ether with HBr. Its
expl props were not investigated
Refs: 1) Beil 6, [795]
2) M. Kohn & G. Löff, Monatsh 45, 612 (1925) & CA 20, 1394 (1926)

3,4,6-Trinitroguaiacol, yel prisms (chlfr), mp 129° (dec), expl weakly by heating under con:
finement. Prepd by cold nitration of 3,5-dinitrocatechol-2-methyl ether
Refs: 1) Beil 6, (395)
2) F. Pollecoff & R. Robinson, JChemSoc 113, 653 (1918) & CA 12, 2314 (1918)
3,5,6-Trinitroguaiacol, monocryst, mp 113.5°, dec 151°, and yel plts, mp 108–9°, dec 145–75° depending on rate of heating; dif sol in cold w. Prepd by nitration of 3-nitrocatechol-2-methyl ether or of 3,6-dinitroguaiacol. Its expl props were not investigated. 


Tetrinitroguaiacol, HO.C₆(NO₂)₄.OCH₃, not found in Beil

GUANIDINE AND DERIVATIVES

Guandine (Gu) (Imino-urea) (Kohlensäure-diamid-imid, in Ger), H₂N.C(NH).NH₂, mw 59.07, N 71.14%; colorless, very hygr crystals, mp about 50°, decom at 160°; very sol in w. In addition to being very hygroscopic, Gu rapidly absorbs carbon dioxide from the zir. In aq soln the base strength of Gu is comparable with that of NaOH. Gu was first prepd by Strecker in 1861 (Ref 2) by the oxidation of guanine (found in guano) with KClO₃ in the presence of HCl. Strecker also prepd these salts: carbonate, hydrochloride, nitrate, oxalate, and double salt of GuHCl with platinum chloride. He assigned the empirical formula C₉H₄N₃, but did not give a structural formula.

A little later Erlenmeyer (Ref 3) prepd Gu salts by reacting an ammonium salt with an aq soln of cyanamide: H₂N.CN + NH₃ = GuHₓ. Currently Gu nitrate and hydrochloride are being made in the USA, with some carbonate being imported. The nitrate is prepd by reacting 1 equiv dicyandiamid (cyano guanidine) with 2 equivs of Ammonium Nitrate in liq ammonia in an autoclave at 160° for 1 hr; this gives a 92% yield of 91% pure Gu Nitrate, which is adequate for the manuf of Nitroguanidine (NGu).

The hydrochloride is prepd by heating ammonium chloride with dicyandiamid, dry. Other salts may be prepd by reacting a Gu salt with a salt of the “acid” desired. Gu may also be prepd by the ammonolysis of urea or thiourea:

H₂N.C:CH₃.NH₃ + NH₃ = GuHₓ + H₂X

Laboratory Preparation of Guanidine (American Cyanamid Co). Mix 100g of Gu carbonate with 400ml w and maintain below 25°. While stirring slowly, add a slurry of 43g of Ca(OH)₂ in 50ml w. Agitate for 15 mins and filter. Wash with small portions of w until filtrate plus washes approach 550ml. This soln will contain approx 10% free Gu, and should be stored under 25° to avoid decomp (See also Ref 5, p 13 for prepn of Gu from the sulfate). Four methods of prepn are listed in Refs 6 & 11.

Properties of Guanidine. In aq soln at RT Gu will decom in a few days to urea, ammonia, and carbon dioxide (faster at higher temp or in the presence of alkali). Gu forms salts, even with weak acids, the strong acid ones being stable to boiling w. Gu does not appear to be toxic, but one study (Ref 8) found this order of relative toxicity (in increasing order):
phosphate, carbonate, nitrate, chloride, and thiocyanate. Gu has large quantity usage in the synthesis of pharmaceuticals, dyes, cationic resins, and NGu. Some of the salts to be described next have found use in the exps industry, and may be prepd from the others. One study (Ref 10) found this order of thermal stability (decreasing) perchlorate, chloride, nitrate, and picrate

Other derivs which are expl or serve for prepn of exps are:

\( \text{N-}^\text{-Hidroxyethyl}, \text{N-nitroguanidine Nitrate} \)
(See Hydroxyethylguanidine under "H", and Trinitrophenylnitroguanidine (See Nitrophenylguanidine under "N")

8) Guanidine salts) (Prepn of Gu by heating Amm metophosphate with urea at 250; prepn of szts by adding appropriate acid at end - nitrate & picrate) 8) A. Shansky, AmPerfumerCosmet . 78(129), 29-30(1963) & CA 60, 11262(1964)
(Differential thermal analysis of nitramines, amine szts, and guanidine derivatives) 11) CondChemDict (1971), 428-L

Guanidine Chlorate (GuCl),
\( \text{H}_3\text{N}_2\text{C}^\text{N}^\text{H}^\text{NH}_2\text{H}_2\text{ClO}_3; \text{mw} 143.54, \text{N} 29.28\%, \text{OB} \text{to} \text{CO}_2 \text{and} \text{Cl}_2 \text{–}22.3\%; \text{colorless crystals, mp 148\textdegree\text{(dec, Ref gives 98–100\textdegree for apparently pure material); sol in w. May be prepd by the double decomp of Gu Sulfate and Ba Chlorate, and evapo of the resultant soln over a w bath until crystals appear. As indicated in Ref 4, the thermal stability is not very high. This material is a mild exp which burns away when touched with a flame or a drop of sulfuric acid (cond.) The same Ref indicates that its impact sensitivity is comparable to PA. It was proposed as a component of expl mixtures with such fuels as C, S, Si, AI and an oxidizer like K nitrate

Guanidine Chromates (GuChr). Three chromate salts are known: the mono (Gu)_2H_2CrO_4; yellow, sp gr 2.301; the di (Gu)_3H_2CrO_4; red-yellow, sp gr 2.502, and the tri (Gu)_2H_2CrO_4; red plates or bipyrs, sp gr 2.595. There is also a perchromate (Gu)_6H_2CrO_4·H_2O; yellow-brown prisms. The latter is prep'd by adding 33% peroxide to freshly prep'ed "chromate", and demonstrates no expl' props; by heating an aq soln of the perchromate one may obtain the monochromate. The other chromates, including mono, may be prep'd by gentle heating of appropriate amounts of chromic anhydride and Gu_2H_2CO_3 in w. All are easily soln in w except the perchromate. Heating the dry materials causes decomps, and doing it confined causes exlns — mild for the mono and violent (190°) for the di salt. The chromates have some use as corrosion inhibitors.


Guanidine Fluorochromate.
H_2N.C:NN.H.HCrO_4; f; mw 179.07; orn-yell scales, expl on heating; sol in w. May be prep'd by dissolving 0.02 mole of chromic anhydride in a minimum of w, adding 3 mls if 40% HF, then adding 0.02mole of Gu_2H_2CO_3, and evaporating over sulfuric acid. Darkens in daylight, etches glass even when dry, dec in damp air evolving HF, and apparently hydrolyzes in w to fluoride and chromate ions.


Guanidine Hydrochloride (Guanidiniumchlorid, in Ger) (Gu.HCl); H_2N.C:NN.H.HCl; colorless nlds, sp gr 1.344 at 30°, mp 184°, sol in g/100g: 215 in 20° w, 320 in 55° w, 67 in 78° alc, insol in 50° acet, 60° benz, and 50° hex. Was first prep'd by Strecker in 1861 (Ref 2). It may be prep'd by treating Gu C with hydrochloric acid. Delitsch (Ref 3) made it from Gu thiocyanate, reacting with Cu sulfate to give Gu sulfate, which reacts with Ba hydroxide to give free Gu, and reacting with HCl. Gu-HCl is slightly toxic when taken internally; aq solns or wet Gu-HCl in contact with the skin are also toxic.

It has been used as an exceptionally watersol source of Gu for org syntheses (Ref 5).


Guanidine Nitrate (GuN), H_2N.C:NN.H.HNO_3; mw 222.09, N 45.80%, OB to CO_2 — 26.2%; colorless crys, mp 214.2°, sp gr 1.430 at 30°, sol in g/100g: 15 in 20° w, 47 in 55° w, 200 in 100° w, 13 in 78° alc, sl in 50° acet, insol in 60° benz, and insol in 50° hex. May be prep'd directly from calcium cyanamide by hydrolysis to cyanamide, which is heated to form dicyanamide and then heated with two equivalents of AN at 160° to give GuN. Since this has the drawbacks of requiring 3 mols of AN per mol of GuN made, and the expl hazard of carbonaceous impurities in the calcium cyanamide, the cyanamide or dicyanamide is preferably separated first before proceeding. Padet al (Ref 5) describe a method starting with dicyanamide and AN. Eventually liq ammonia was used as a diluent for the large amount of heat evolved. Older methods are given in Beil (Ref 1) and Davis (Ref 3, 378—9).

Laboratory Preparation. Davis (Ref 3, p 380) gives this method: On a 160° oil bath heat a 1-liter flask contg an intimate mix of 210g dicyanamide and 440g AN. After 2 hrs, cool to RT. Then place on a steam bath and extract.
the contents with several portions of hot water, decanting each portion and combining all. Reheat to dissolve, and filter while hot to remove the insoluble ammelide and ammelide. Concentrate the soln. to about 1 liter and cool. Decant the mother liquid and concentrate further to 1/4 liter. Combine both crops, redissolve in the least amount of water, cool, filter, and dry. The product is suitable for laboratory prep of GuN. GuN may be considered a very weak expl with Trauzl test value of only 10% TNT, deton vel of 3700 m/s. It is very insensitive to impact, or even expl primers, failing to detonate under the impact of a 10 kg wt falling 3.1 m (Ref 11). Heat of combustion is 1715 cal/g at const vol and weight loss (liq), and heat of formation varies given as 88–97 kcal/mole.

GuN is used as an ingredient of some Blasting Expls and for the prep of the expl NGu (Refs 15 & 19).


Guanidine Nitroform (GuNf), H₂N.C:NH₂.HC(NO₃)₂; mw 210.12, N 40.01%, OB to CO₂ 7.76%; yel ndls, sp gr 1.64, mp 128° (86.4–7.4° for a monohydrate); sl sol in cold water. Prep by J.V.R. Kaufman of Picatinny Arsenal from a very dilaq Gu soln and Nitroform at RT. It may also be prep from Gu₂H₂CO₃ and Nitroform. The impact sensitivity with a 2kg wt on PicArsn App is 11° compared with 14° for TNT. Even though it is one of the most stable organic Nitroform salts, the termal stability is unsatisfactory. It explodes after 30 hrs in the 100° vacuum test. Deton vel is comparable with RDX. It does not react with dry aluimun at 90°.

Refs: 1) Beil, not found 2) O.H. Johnson & F. Taylor Jr, NAVORD Rept 2125(NOL) (1951) (Guanidine Nitroformate and Hydrazine Nitroformate as possible new HE's) 3) W.F. Sager & D.V. Sickman, NAVORD Rept 483 (1952) (Research and development in new chemical high explosives)
Guanidine Oxalate (GuOx1), H₂N.C.NH₂.H₂O₃.C₂ H₂ O₄; mw 149.11, N 28.2%, OB to CO₂ – 59.1%; colorless crystals from w as a hydrate, mp (dec above 200°); diff sol in cold w. First prepd by Strecker by treating Gu₂H₂C₃O₃ with oxalic acid. Potentially a good flash-reducing agent
Refs: 1) Beil 3, 86 & (40) 2) A. Strecker, Ann 118, 162 (1861) 3) M. Raffe & O. Balduzzi, GazzChimItal 47, 1, 70 (1917)

Guanidine Perchlorate (GuPchl), H₂N.C.NH₂.HClO₄; mw 159.54, N 26.34%, OB to CO₂ and ½Cl – 10.0%; colorless crystals, sp gr 1.1-1.67, mp 248°, bp (expl about 367°C); sol in w (11.5%, w/w, at 0°C), HClO₄ (36.7%, w/w, and from a monoperchlorate solvate, mp 62.2°C). May be prepd by mixing equimolecular amounts of Gu and HClO₄, or by heating dicynamidine and Amm perchlorate in an autoclave at 150-160°C. GuPchl is a powerful expl, much more sensitive to impact than PA (50 cm compared with 85 cm with a 2 kg wt on BurMines App). Deton vel is 6000 m/s at sp gr 1.15, and 7150 m/s at 1.67. The Pb Block Expansion (Trauzl Test) is 400 cc for a 10 g sample. In comparing the brisance with NGu and GuN by the Pb Plate Test, Stettbacher (Ref 9) found that these two only dented the plate, but GuPchl punctured it. GuPchl was proposed (Ref 2) as an ingredient of expl mixts, and was patented in Ger for use in expls (Ref 4)
12) V.Ya. Rosolovskii et al, ZhNerogl-Khim 12(5), 1275-81 (1967) & CA 67, 85457 (1967) (Perchloric acid as a solvent of organic perchlorates) 13) Ibid 13(3), 681-6 (1968) & CA 69, 13538 (1968) (Energy of the addition of perchloric acid to amines and the heats of formation of amine perchlorates) (Give for the heat of formation of GuPch1-HClO₄ – 97.2 kcal/m; for the heat of addition for GuPch1 – 45.9 kcal/m for the heat of addition of GuPch1-HClO₄ from GuPch1 – 14.7 kcal/m) 14) R.N. Isaev et al, IzvVysshUchebZaved, KhimKhimTekhnol 13 (8), 1089-92 (1970) & CA 73, 132626 (1970) (Effect of additives on the thermal stability of GuPch1 and its mixts) (Stability decreased by 10% ferric oxide, and increased slightly by 10% ZnO) 15) J.J. Byrne, USP 3531338 (1970) & CA 74, 14697 (1971) (Propellant contg GuPch1-LiPch1 eutectics in homogeneous phase with polymeric binders) (GuPch1/LiPch1, mp: 70/30, 126.5°C; 66/33.2, 151°C; 57.5/42.5, 110°C. These are much less sensitive to impact than LiPch1 alone. The polymerization of the binder should not produce w, eg, acrylamide is acceptable)

Guanidine Picrate (GuPicr or GuP), H₂N.C.NH₂.HOC₆H₄(NO₂)₃; mw 288.18, N 29.17%, OB to CO₂ – 63.8%, sp gr about 1.5. GuPicr exists in two stereoisomeric forms: Labile – it yel ndls, sl sol in w (0.8 at 80°C). May be prepd by reacting PA with free Gu Stabile – deep yel plates, sl sol in w (0.574 at 80°C); diff sol in alc & eth. May be prepd by the action of Gu on sol Picrates
Generally a mixt results on prep, giving a mp range of 310-333°C with decomps as low as 280°C
GuPicr is an expl with deton vel about 6500 m/s. It is less sensitive to impact and shock than AmmPicr and thus may be used as a filler for armor-piercing shells. Its thermal stability is satisfactory. Its use as an expl dates from about 1901 when it was patented in Ger for use in commercial expls. When mixed with sufficient K nitrate to give a zero oxygen balance, the resultant powdery mixture can absorb up to 1/3 its weight of NG, and becomes somewhat preferable to regular Dynamites (Ref 2). Olsen (Ref 3) patented GuPicr
as a filler for projectiles, alone, or blended with paraffin or TNT and compressed to no lower than sp gr 1.5. The following are some published formulations for commercial expls: GuPier 40–30 and KNitrate 60–70, or GuPier 75 and NG 25, or GuPier 80–75 and KClO₃ 20–25%


Guanidine Sulfate (GuSulf),
(H₂N₃C·NH₂)₂H₂SO₄·(½H₂O); mw 225.23, colorless crysts; sol in w; insol in alc & other org solvents. Was first prepd in 1861 by Strecker (Ref 2). May be prepd by treating dicyandiamide with 75% sulfuric acid at RT (Ref 3). Stettbacher (Ref 4) heated dicyandiamide with an excess of 50% sulfuric acid. More recently Mackey (Ref 5) fused 300g of urea with 1140g of Amm sulfamate, NH₄SO₃·NH₄ at 225–45° for 30 mins, and then extracted with w to give 338g of GuS. Treating Gu carbonate with sulfuric acid is also effective.

GuSulf may serve for the prep of the free base by treating with Ba hydroxide in w, or with NaOH or NaNH in liq ammonia. It has been used as a fireproofing agent, as an intermediate in the prep of surfactants and pharmaceuticals and for prep of resins


Guanidine Tetraperoxoniobiate,
(H₂N₃C·NH₂)₂[NbO₂]₄; N 31.42%, OB to CO₂ and ½Nb₂O₅ 37.9%; crysts, expd below 100° on rapid heating, dec 130° on slow heating; sol in w; insol in alc. Was prepd from NbCl₅, 10% H₂O₂, and Gu₂·H₂CO₃


Guanidine Thiocyanate (GuTh),
H₂N₃C·NH₂·HNCs; mp 118.17, N 47.4%, colorless deliq lfts, mp 118°; sol in w (134.93 g/100g at 15°), EtAc (20g/100g at 25°), acet & aq alc. Was first prepd by Delitsch in 1874 (Ref 2). Accdg to Davis (Ref 4) it may be prepd by heating Amm thiocyanate for 20 hrs at 170–90°, or until H₂S is no longer evolved. Presumably, the reaction involves the formation of thio urea, its conversion to cyanamide, and reaction of the latter with undecomposed thiocyanate. The storage instability of cyanamide precludes its direct use for this prep. Werner & Bell (Ref 3) prepd GuTh in nearly theoretical yield by heating 1 mole of dicyandiamide with 2 moles of ammonium thiocyanate for 2 hrs at 160° to give 2 moles of GuTh. Ref 1 offers other methods

GuTh was formerly one of the most common salts of Gu, serving as the parent of other salts thru metathetical reactions. It also served as starting material for NGu by direct nitration with mixed acid. The NGu obtred proved to be unsuitable for use with NC because of the sulfurous impurities which reacted with the NC in storage. A strong aq soln of GuTh will dissolve cellulose (Ref 4)

Refs: 1) Beil 3, 169, (70) & [121] 2) G. Delitsch, JPraktChem 9, 1–6 (1874) 3) E.A. Werner & J. Bell, JCS 117, 1133 (1920) 4) Davis (1943), pp 375, 379

Analytical Procedures and Tests for Guanidine and Its Salts. Gu, urea, their salts, covalent compounds, and polymers have the property of evolving ammonia when heated to 250°, which is not shared by other amines or amides. Thus, after a preliminary heating at 180° for several
minutes in a test tube of a small amount of sample, the tube is covered with filter paper treated with Nessler's Reagent and heating is continued to 250°; yell or brn coloration indicates the presence of any of these classes of material (Ref 6). Sullivan (Ref 1) describes a spot color test involving the reaction with 1,2-naphthoquinone-4-sulfonate. For quantitative analysis, the preferred method according to the article on Gu in Kirk & Othmer (Ref 19 under Gu) is potentiometric titration with HClO₄ in ethylene glycol methyl ether. Next best is the gravimetric determination involving precipitation with calcium picrate, most recently discussed by Fainer & Myers (Ref 5). A modification of the picrate method is discussed by Ghosh & Sarkar (Ref 9) who prefer to use magnesium bis-trinitrophenylamide, Mg[N(NTNB)₂]₂, as the precipitant. The min detectable amount of Gu is 0.5% in w, and, with precautions, no interference from AN, urea, melamine or dicyanodiamide is encountered.


NITROGUANIDINE (NGu) (Picric: GuDol in Ger), H₂N.C:NH.NH.NO₂; mw 104.07, N 53.84%, OB to CO₂ ~30.8%; sp gr 1.81, mp 232° if the temp be raised at a moderate rate, values between 220 and 250° have been observed (Ref 12). NGu was first prepd in 1877 by Jousselin [CR 85, 548 (1947) & 88, 874 (1879)] by dissolving dry GuN in fuming nitric acid and passing nitrous oxide thru the soln. By drowning the soln in w, he obtb a ppt which he called "Nitrosoguanidine", but which was later proved to be NGu by J. Thiele [Ann 270, 1 (1892)]. Thiele found that it is easier to prep NGu by treating GuN with sulfuric acid (See below). Davis & Elderfield [JACS 55, 731 (1933)] found that phosphoric acid is also an effective dehydrating agent.

NGu exists in at least 2 cryt modifications, an alpha and a beta. The alpha form may be prepd by dissolving GuN in concd sulfuric acid and drowning in w. It crystallizes from hot w as long, thin, flexible, lustrous ndls which are tough and pulverize with difficulty. It is the form most commonly used in the expl industry. The beta form may be prepd (along with a small amount of alpha) by nitrating a mixture of GuSulfate and Amm sulfate. It crystallizes from hot w in fern-like clusters of small, thin, elongated plates. The beta may be converted into the alpha by dissolving in concd sulfuric acid and drowning in w.

Laboratory preparation of NGu. Davis (Ref 6d, p 381) gives this procedure: Immerse a 1-liter beaker contg ½ liter of concd sulfuric acid into cracked ice and stir until the contents are at 10° or less. In small portions add 400g of dry GuN with stirring to keep the temp under 11°. When all of the GuN has dissolved, draw the milky liquid in 3 liters of cracked ice and w. Let stand until completely pptd, then filter thru a Büchner funnel and rinse to remove...
excess acid. To purify, dissolve in about 4 liters of boiling w and let stand overnight. Filter and dry to get a 90% yield.

**Plant preparation of NGu:**

1st method: By dissolving GuN in concd sulfuric acid in the manner described in Laboratory Procedure. However, correspondingly larger amounts are used, depending on the size of the equipment.

2nd method: By fusing equimolecular quantities of urea and AN:

\[ H_2N.COH.NH_2 + NH_4NO_3 \to H_2N.C(NH).NH.NO_3 + 2H_2O, \]

and then recrystallizing the product from boiling w (yield about 92%)

3rd method: By heating a soln of equimolecular quantities of cyanamide and AN in an autoclave at 160° and 200 lbs pressure:

\[ H_2N.CN + NH_4NO_3 \to H_2N.C(NH).NH.NO_3 + H_2O, \]

and then recrystallizing the product from boiling w (yield about 88%)

For many years (before and for sometime after WWI), NGu, as well as many other derivs of Gu, was prep'd from Gu thiocyanate, one of the cheapest and easiest to prepare of the Gu salts. The thiocyanate used to be the principal industrial product of Gu. However, NGu prep'd from thiocyanate by direct nitrilation with mixed acids always contained traces of sulfur comps. When such NGu was used with NC in smokeless proplnt, the sulfur comps attacked the NC and thus lowered the stability of the proplnt. This was one reason why NGu powder did not come into earlier use (Ref 6d, p 375)

Both forms of NGu have the same mp (about 232°) and are alike in most of their chemical and physical props. However, they differ slightly in solubility in w except at 25° and 100°, where their solubility curves cross, giving 0.42-0.44g per 100ml at 25° and 8.25g at 100°. Solubility between 25 and 100° is slightly lower for the α- than for the β-form, while at 0° it is about 0.12 for both forms. Both forms are sol in alc and nearly insol in eth. Solubility in 1N KOH is 1.2 at 25°

Solubility in aqueous H₂SO₄ (Ref 6d, p 383):

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**Explosive Properties of NGu:**

**Booster Sensitivity Test:** Min wt of Tetryl pellet at sp gr 1.41 to produce 50% deton is 100g, with 0.67 wax spacer (Refs 22a & 29b)

**Brisance:** Plate dent test, about 95% of TNT at sp gr 1.5. Lead block crushing = 40g of NGu placed on a block 67mm in diam produced a shortening of 7mm compared with 10.5mm for PA (Ref 6d, p 391 and Refs 22a & 29b)

**Brisance by Sand Test:** 36.0g (TNT 48.0g) or 73.5% of TNT (Refs 22a & 29b)

**Covolume:** 1.08 (Ref 6d, p 339)

**Detonation Velocity:** 5360m/s at sp gr 1.0 and 7650 at sp gr 1.5 (Refs 22a & 29b)

**Explosion Temp:** dec at 275° (5 sec) (Refs 22a & 29b)

**Force:** 9660 (Ref 6d, p 391)

**Fiction Pendulum Test** - unaffected by fiber or steel shoe (Refs 22a & 29b)

**Gas Volume:** 1077cc/g (Refs 22a & 29b)

**Heat of Combustion:** 1995cal/g (Refs 22a & 29b)

**Heat of Explosion:** 721cal/g (Refs 22a & 29b)

**Heat of Formation:** 227cal/g (Refs 22a & 29b)

**Heat Test at 100°:** Loss in wt 0.48 in 1st 48 hrs, 0.09% in 2nd 48 hrs and no expln in 100 hrs (Refs 22a & 29b)

**Hygrosopicity:** non-hygrosopic at 30° & 90% RH (Refs 22a & 29b)

**Impact Sensitivity:** BoFm App, 2kg wt, 47cm, or more sensitive than either TNT or PA (Refs 22a & 29b); PicArsn App, 1 lb wt 26 inches (Refs 22a & 29b)

**International Test at 75°:** Loss in wt 0.04% in 48 hrs (Refs 22a & 29b)
Power: Ballistic mortar, 104% TNT; Trauzl test, 101% TNT (Refs 2a & 29b)
Pressure of Explosion (max): 4078 kg/sq cm at sp gr (loading) 0.03 (Ref 6d, p 389)
Rifle Bullet Impact - unaffected (Refs 22a & 29b)
Sensitivity to Initiation - min chge LA 0.20g & Tetryl 0.10g (Refs 22a & 29b)
Storage: (dry)
Temp of Explosion: about 2098° as compared to 2820° for TNT. Patarr (Ref 3, p 153) gives the temp for NGU as low as 907°; but this appears to be erroneous
Thermal Stability: satisfactory (Refs 22a & 29b)
Vacuum Stability at 100°: 0.37cc gas evolved by 1 g in 48 hrs (Refs 22a & 29b)
Volatility: none (Refs 22a & 29b)

The above data indicate that NGU is a HE resembling TNT and PA in its props, although giving a considerably lower sand test value
Uses: During WWII, NGU (50) was used by the Germans, in admixtures with AN (30) and paraffin was (20%), for filling trench mortar shells (Ref 6d, p 391)

Due to the low temp of expln of NGU, the possibility of its use as a temp reducing agent was investigated as early as 1901 by Vieille (Ref 2, p 195). This famous French expl expert found that, if 10 to 15% of NGU was incorporated in NC, the resulting proplnt was practically flashless and less erosive than those with expls of comparable force (See also Ref 6d, p 388). Investigations with NGUs were carried out later in France by Patarr (Ref 3) and Muraour & Aunis (Ref 6); in the US by Davis, Ashdown, Elderfield (Ref 4); Davis & Abrams (Ref 5); Smith (Ref 5a); and in Germany by chemists of the Dynamit AG and others. The use of NGUs in proplnts was, however, rather limited because the commercial product attacked NC in storage. This seemed to be due to the presence of sulfur compds in the NGUs, derived from the Gu thiocyanate, which served, usually, as a primary material for the prepn of NGUs (See Note, under prepn of NGUs). When the method of prepn was changed and the sulfur compds were absent, it was possible to prep more stable proplnts

German Gen U. Gallwitz, killed in action on the Russian front during WWII, was one under whose direction the cool, flashless, non-erosive proplnts contg NGU and DEGN were developed in Germany before and during WWII. Proplnt contg NGU was called Gudol Pulver (abbr "G" Pulver) in Germany (Ref 8, p 80, Ref 9 and cross refs listed under GUDOL PULVER). The first successful Gudol Pulver was prep'd in Germany in 1937 by Dynamit AG. This proplnt gave muzzle flashlessness in light field howitzers without the addition of suppressing agents (flash-reducing agents) such as K sulfate, and the quantity of smoke was small. In the case of guns of larger caliber, the charges required comparatively small additions of flash-reducing agents to render them flashless. Addition of NGU not only suppresses the muzzle flash, but also eliminates the "breech flash", which is especially noticeable in modern guns (used in armored vehicles) equipped with muzzle brakes and automatic and semi-automatic closures. A most particular advantage of Gudol proplnt is the increase of the barrel life

Following are examples of some Gudol proplnts:

1) NC (12% N) 44.00, DEGN 18.85, NGU 20.00, DNT 5.50, o-Nitronaphthalene 2.00, diphenylurethane 1.50, ethylphenylurethane 1.50, K nitrate 4.00, hydrocellulose 4.00, akardite 0.40, MgO 0.15 & graphite 0.10%. This proplnt has a heat of combstn (calorific value) of 720cal/g (compared with 950 and 820 cal for some NG proplnts) and is suitable for various guns. When used in anti-aircraft guns, this proplnt increased the barrel life of a gun from 1700 firings (as experienced with NG proplnts with a calorific value of 950 cal) to about 15000 firings (Ref 8, p 88)

2) NC (12% N) 42.45, DEGDN 18.20, NGU 25.00, diphenylurethane 4.50, ethylphenylurethane 4.50, K sulfate 5.00, MgO 0.25 & graphite 0.10%. This proplnt had a calorific value of 730cal/g and was used in most of the Naval guns (Ref 8, p 91). NGU was also used as an ingredient of proplnts by other countries, including the US

Following is an example of an American NGU proplnt, as given in Spec MIL-P-668A (Feb 1955): NC (13.3 to 13.4% N) 18.0 to 22, NG 18-20, NGU 52.7-56.7, ethyl centralite 5.40-6.60 & cryolite 0.20-0.40%. It should be noted that flashless colloided proplnts contg NGU produce a considerable amount of particulate gray smoke (more than other proplnts used
in the US) smelling of ammonia (Ref 6d, p 387) [See also "Cool (or Cooled) Propellants" in Vol 3 of Encycl, pp C509-R & C510-L].

References on Nitroguanidine: 1) Beil 3, 126, (59) & [100] 2) P. Vieille, MP 11, 195 (1901) 3) G. Pataut, MP 13, 153, 159 (1905–06) 4) T.L. Davis et al, JACS 47, 1063 (1935) 5) T.L. Davis & A.J.J. Abrams, Proc Amer Acad ArtsSci 61, 437 (1926) & CA 21, 1968 (1927) [Transformations of Nitroguanidine] 5a) G.B.L. Smith et al, IEC 23, 1127–29 (1931) [Preparation of Nitroguanidine] 6) H. Muraoir & G. Aunis, MP 25, 91 (1932–33) 6a) A. Stettbacher, Nitrocellulose 7, 141–5 (1936) & CA 30, 8165 (1936) [Methods of prep of NGu from dicyandiamide and from GuSulfate are described. In the latter, 100g of GuSulfate were nitrated with 360ml of mixed acid contg 98.2g nitric. The brisance of NGu as determined by the Lead Plate Test proved to be lower than that for the corresponding amount of GuPch] 6b) T. Urbanski & J. Skrzynecki, RocznikiChem 16, 353–8 (1936) & CA 31, 2502 (1937) [Thermal analysis of mixedtures containing AN, GuN & NGu] (The following eutectics were obtd: AN 80, NGu 20% at 131.5°; GuN 59, NGu 41% at 166.5°; AN 60, GuN 22.5, NGu 17.5% at 113.2°) 6c) R.C. Elderfield, "Explosives from Hydroxy and Amino Compounds", OSRD No 158 (1942) PB Rept No 31094 (1942) and OSRD No 907 (1942) PB Rept No 31085 (1942) 6d) Davis (1943), 380–91 7) Bebie (1943), p 110 7a) W.H. Rinkenbach, PATR 1336 (1943) [Thermochemical & physical tests of NGu propants] 8) O.W. Stockland, "General Summary of German Explosive Plants", US Office of Tech Service, PB Rept No 925 (1945) 9) U. Gallwitz, "German Powder Development from 1918 to 1942", PB Rept No 47059 (1945) 9a) Aner Cyanamid Co, BritP 571527 (1945) & CA 41, 1900 (1947) [Crystalline NGu in an extremely fine state of subdivision] & BritP 572231 (1945) & CA 41, 6896 (1947) [Crystalline NGu] 10) J.H. Peden et al, IEC 39, 952–58 (1947) 10a) E.J. Pritchard & G.F. Wight, CanJRes 25F, 257–63 (1947) & CA 42, 369 (1948) [Production of NGu with high bulk density] 10b) G.H. Foster & E.F. Williams USP 2445478 (1948) & CA 42, 7986 (1948) [Rapid crystall of NGu from aq soln in the presence of a compd having an amino or subst amino group (such as ethylenediamine) produces small, very stable crystals (2½–20 micron) suitable for incorporation in propellants] 10c) C.M. Mason & G. von Elbe, "The Physics and Chemistry of Explosives Phenomena", Ordn Project TA 3–5001, USBur Mines (June 1948), p 4 (Sol of NGu in dimethylformamide is 10.6% at 30° and 13.9% at 40°) 10d) M. Dutour, MP 31, 73–80 (1949) & CA 46, 11685 (1952) [Explosive properties of NGu] [Sensitivity to initiation as a function of density; compressibility; coefficient of practical utilization (CUP) alone and mixed with Al; vel of deton as a function of density; impact, gap, and combustion tests] 11) Cyanamid's Nitrogen Chemical Digest, Vol IV, "The Chemistry of Guanidine", Am Cyanamide Co, NY (1950) 11a) G. Bourjol, MP 32, 11–25 (1950) & CA 47, 3243 (1953) [Preparation of NGu by dehydration of GuN with concd sulfuric acid]: (GuN plus enough 94–95% sulfuric to give 85–88% acid at end of reaction, at RT but all right to reach 35–40° at the end) 12) W.C. McCrone, AnalChem 23, 205–6 (1951) [Crystal-line structure of NGu as determined at atmospheric pressure – orthorhombic system. NGu sublimes before melting to give a few separate distinct cysrs. Melting occurs at 246–47° with considerable decomp. If the melting process is stopped before completion, the un-sublimed portion which was almost completely melted, crystallizes as fine needle aggregates in a terrace-like pattern, characteristic of compounds that melt with decomp] 13) J.N. Pring, USP 2557463 (1951) & CA 45, 9863 (1951) [Propplnt comp of NGu 55, NC 19, NG 18.7 & DEDpHurea 7.3% may be prep'd by solventless or solvent process to have a specific surface of 9000–22000sq cm/cc and a calorific value of 650–825cal/g] 14) A.F. McKay et al, CanJChem 29, 746–58 (1951) & CA 46, 2501 (1952) [Structures of NGu and its derivs, 18 refs] 15) Ibid, 391–7 (1951) & CA 46, 7095 (1952) [Prepn of substituted NGu's and the cyclization of 1-(3-Nitroxybutyl)-3-nitroguanidine] [An amine or diamine was used to disp the Men(NO)- radical from Men(NO.C:NNHNO₂ giving eg, 1,2-bis(3-Nitroguanidino)ethane, mp 248°(dec); 1,3-bis(3-Nitroguanidino)propane, mp 234°(dec); 1,3-bis(3-Nitroguanidino)butane, mp 230°(dec); 1,4-bis(3-Nitroguanidino)butane, dec over 265°; 1-(3-Nitroxybutyl)-3-nitroguanidine, mp 125°] 16) A.F. McKay, ChemRev 51, 301–46 (1952) & CA 47,
4844 (1953) (Nitroguanidines) 17) V. Ostoja, Technika (Belgrade) 12, 770-4 (1957) & CA 52, 14171 (1958) (Crystalization of NGu for obtg finely crystallized powder suitable for exps and use of protective colloids, preferably aqueous starch or gelatin) 18) W. Schemuth, GerP 1010888 & 1013556 (1957) & CA 54, 7936, 9774 (1960) (NGu with a large specific surface area and sulfuric acid-free NGu) 19) M. Thoma & H. Hagn, GerP 1004090 & 1005426 (1957) & CA 54, 18961 (1960) (NGu with a high specific surface area and treatment of the NGu-sulfuric acid reaction mixture) 20) R.A. Henry & J. Cohen, USP 2946820 (1960) & CA 55, 393 (1961) (High bulk-density NGu and recryst NGu from aq soln contg a little HAc and a little of a deriv of NGu such as hydrazine, hydrazide, amide, amine, sulfonamide, sulfate) 20a) CondChemDict (1961), 805-R (NGu) 21) L.D. Sadwin, Science 143 (3611), 1164, 1169 (1964) & CA 60, 14188 (1964) (Explosive welding with NGu) 22) Kirk & Othmer 8 (1965), p 625-6 (NGu) 22a) Anon, "Properties of Explosives of Military Interest", AMCP 706-177 (1967), pp 239-42 23) Y.P. Carignan & D.R. Sarriana, JOC 32 (2), 285-9 (1967) & CA 70, 10960 (1969) (Differential thermal analysis of NGu's, amine salts, and Gu derivs) 23a) Poudreries Réunies de Belgique, SA, BelgP 717436 (1968) & CA 71, 51832 (1969) (NGu recovery from triple-base exps; crush under w to about 1 mm, extract the Nitroglycerol with methylene chloride; extract the NGu from the residue with w) 24) J. Savitt, Wrs State Sect, Combust Inst (Pap) 1968, WCS/Ct-68-31, 10pp & CA 73, 16945 (1970) (Detonation sensitivity of very low density pressings of NGu) (At 0.45-1.00g/ml in a 2-inch diam cardboard confinement, sensitivity to a No 8 cap decreases normally as sp gr increases; at 0.16-0.45g/ml, the sensitivity increases as sp gr increases) 25) E.I. Isaev et al, TrKonfAnalKhimNevodnRastvorovVkhFiz-KhimSvostv, 1st 1968, No 1, 65-8 & CA 72, 96451 (1970) (Effect of nonaqueous solvents on acid-base properties of NGu) (Acidic in dimethylformamide, pyridine and acet; base in HAc and formic acid) 26) E. Ripper, Explosivst 17 (7), 145-51 (1969) & CA 72, 48454 (1970) (α- and β-Nitroguanidine) (Reinvestigation of both forms by IR, UV, Nuclear Magnetic Resonance (NMR), Differential Thermal Analysis (DTA), thermogravimetric & X-ray showed marked diffrences in crystal habit and behavior to heat, the α-dec at loe er temp) 27) D. Price & A.R. Claimont, Jr, 12th SympCombstn (1968), (Pub 1969), 761-70 & CA 75, 8070 (1971) (Explosive behavior of NGu) (Crt diam of high bulk-density is about 3X that of low bulk-density, but the relative difference in shock sensitivity is not that great) 28) W. Kemula et al, BullAcad-PolonSci, SerSciChim 18 (8), 455-61 (1970) & CA 74, 7187 (1971) (N-nitroderivatives. Equilibriums of Nitrourea and NGu in aq soln) (NGu and its tautomeric acid form are in equilibrium at pH 13.6) 29) E. Ripper, Chimld, Génie-Chim 103 (14), 1763-65 (1970) & CA 75, 8055 (1971) (α- and β-NGu) (Review of available data) 29a) CondChemDict (1971), 623-R 29b) AMCP 706-177 (1971), Same pp as in Ref 22a 30) G.A. Lobanov & L.P. Karmanova, IzvVysshUchebZaved, KhimKhimTekhnol 14 (6), 865-7 (1971) & CA 76, 28438 (1972) (Enthalpy of formation of some organic substances) (NGu=22.4±0.4 for 1-3mm cryts, and -23.9±0.6 for 0.2-0.8mm cryts) 

Nitroguanidine Explosives

As has been mentioned under "Nitroguanidine", many expl mixtures were patented in which NGu was used in small or large quantities. Its principal use, however, is in smokeless propellants, due to its property of eliminating flash. Not only is it used in colloided NC propgnts, but Hale and Olsen have tried it as a component of smokeless propgnts contg no NC NGu was also proposed for use in expl comps, together with other ingredients, such as fuels (C, S, Al, Si) and oxidizers (K nitrate, K chlorate, K perchlorate)

Following are additional refs of NGu expls:
A) C. Manuelli & L. Bernardini, USP 1409963 (1922) & CA 16, 1868 (1922) (Use of NGu and of various NGu & Gu salts, such as the chlorate, nitrate and perchlorate, in various expl mixts. Other ingredients may be fuels and oxidizers)
B) G.C. Hale & F. Olsen, USP 1547808 & 1550960 (1925) and CA 19, 3021 (1925) & 20, 112 (1926) (A propellant which gives uniform results, is formed of NGu 41, PETN 21, NH₄ClO₄ 32 & triphenylphosphate 6%. NGu may also be
incorporated in NC proplbs. For this, NGu is previously treated with a solvent, such as tolylmethylekone, benzaldehyde, diaeetin or urethane, which also acts as a coloiling agent for the NC)

C) T.L. Davis, USP 1754417 (1930) & CA 24, 2886 (1930) (An expl is formed, comprising NGu and an aliciphatic Nitramine, such as methyl-, ethyl-, dimethyl- or methylbutynitramine. NC may also be included)

D) S. Gordon & E. Whitworth, BritP 616898 (1949) & VA 43, 4856 (1949) (Flashless proplbs, which cause very little erosion, are prep by incorporating in the usual smokeless proplbs

large amounts of NGu and dibutylphthalate, eg, NGu 55±1, DBuPh 10±0.5, NC (colloidal) 20±1, NG 13±1 & diethylphenyleneurea 2±0.3%)

E) A.T. Tyre, USP 2470082 (1949) & CA 43, 5190 (1949) (Permissible expls may be comprised of the following compounds: NGu, GaN, Nitrodicyan amidine, or dicyanamidine nitrate mixed with NaH2PO4, Ca(H2PO4)2, the hypophosphites amounting to 5–35% of the total. Such mixts, when ignited, produce gas but no flame)

F) K.U. Helker, USP 2904420 (1959) & CA 54, 867 (1960) (Self-sustained, non-detonating, gas-producing compositions) [One formula is: GuN32, AN 33.8, K nitrate 3.8, dolomite 24.8, Amm dichromate (sensitizer) 3.7, and Cu oxalate (sensitizer) 2%; NGu may also be used instead of GuN]

G) A. Schloetzer, GerP 1102023 (1961) & CA 57, 16097 (1962) (Polyvinyl nitrate (14.3% N) was combined with an equal amt of NGu to give a workable explnt with a Qf of 834cal/kg & a gas vol of 1246cc/H) R.L. Trask, S. Sage & E.G. Nadel, USP 3086906 (1963) & CA 59, 377 (1963)

(Propnt contg NGu 50–65, NC (12.6% N) 16–23, NG 16–21, dialkylphthalate plasticizer 4.5 & stabilizer 1.5%)

I) E. Richter & R. Meyer, GerP 1656358 (1970) & CA 72, 123585 (1970) (100p NG is added with agitation to 20p 25% alc NC (13.15% N), aged for 6 hrs to produce a clear cuttable, gelatinous mass which is kneaded for 4 hrs with an addnl 110p NC and 120p NGu, with addn of 40p acet and 30p alc to produce a dry explnt of good stability & quality)


(An expl powd contg NGu 9.7, Amm Nitrate 77.7, starch 11.6 and w 1%, is applied to polyethylene sheet overlaid stainless steel sheet and detonated from one end with a percussion cap)

K) H. Schleuter & F. Hermann, GerP 1944844 (1971) & CA 74, 143986 (1971) (Pressed expls of low percusion sensitivity contg NGu and 5–12% eutectic mixts of 2,4,6(C6H4N)3C6H2-NMeNO2 and its N-Et analog. NGu contg 10% eutectic had 8400m/sec deton vel, compared with 7600 for pure NGu)

Nitroguanidine Nitrate, H2N.C-NH.NH.NO2-NHO3; mw167.09, OB to CO2 -4.8%; rhomb prisms, mp 147°(dec). May be prep by dissolving NGu in hot, concd nitric acid and allowing to cool.

Losses the nitric acid in contact with air. The salt is an expl detonable by impact, but not by heat


Nitroguanidine Perchlorate and Diperoxide, H2N.C-NH.NH.NO2-HClO4 and -2HClO4; mw 204.53 and 304.99, N 27.45 and 18.36%, OB to CO2 and ½ or 1 Cl2 +11.7 and +26.2%. The monoperchlorate forms colorless, hygr crystals which dec to NGu and HClO4 at 120°; may be prep by dissolving of NGu in anhydrous HCIO4 sol in HClO4 to 48.1%, wt/wt. The energy of addition in forming this salt is ~21.1kcal/mole; the heat of formation is ~51.5kcal/mole. The diperchlorate may be prep by dissolving the mono- in HClO4. It melts at 70° and explodes at 93°

Nitroguanidine Silver Salt, \( \text{H}_2\text{N.C-NH.NAgNO}_3 \)
mw 210.95, N 26.54%, OB to \( \text{CO}_2 \) and \( \frac{1}{2}\text{Ag}_2\text{O} \)
-15.2%; wh ndls (hot ammonia soln), expl or
defgr on heating; insol in w; sol in acid or
ammonia. May be prep'd by treating a soln of
Ag nitrate in warm w with NGu in the presence
of Ba(OH)_2. It gives an alkaline reaction
Refs: 1) Beil 3, 127 2) J. Thiele, Ann 270,
19(1892)

Nitroguanidine and Derivatives, Analytical
Procedures.
Qualitative Tests for NGu. The presence of NGu
may be detected by one of the following tests
(Ref 1, p 384):
A) To about 0.01g of sample dissolved in 4ml
of cold w, add 2 drops of saturated ferrous am-
monium sulfate soln, followed by 1 ml of 6N
NaOH. Allow to stand for 2 mins and filter.
If NGu is present, the filtrate will have a
fuchsin color, which usually fades after standing ½
hour
B) Mix about 0.1g of sample, 5ml of w and 1 ml
of 50% acetic acid in a test tube and warm at
40–50° until the soln is complete. Add about
1g of Zn dust and place the test tube in a beaker
of cold w for 15 mins. Filter and add to the fil-
trate about 1cc of 5% Cu sulfate soln. If NGu
is present, the soln becomes extremely blue.
Now, if this soln is heated to boiling, it is ob-
served that gas evolves, then the soln becomes
turbid and finally a ppt of metallic Cu is de-
posited. If instead of Cu sulfate soln, 1ml of
Ag acetate soln is added and the liq boiled, a
ppt of metallic Ag is formed
Note: Silver acetate soln is prep'd by shaking
with warming 2g CH_3COOAg crystals in soln of
2ml glacial AcOH in 100ml of w, filtering and al-
lowing to cool

Colorimetric tests for NGu are found in
Ref 20, p C418-R, Vol 3 of Encycl under Tests
for Propellants
Quantitative Analysis of NGu
Accdg to StdMethodsChemAnalysis (Ref 10a,
p 1336), the assay of NGu is made by the con-
ventional nitrometer method (described on p 755
of Vol 1 of StdMethodsChemAnalysis) on a sample
that has been dried at 98 to 102°C (Nitrometer
method is described in Vol 1 of this Encycl, pp
A373-R to A377-R with illustration on p A374-L
and also in this Vol)

It may alternately be detd by the method de-
scribed on p 1394 of Ref 10a under "Nitroguan-
idine by Buffered Titanous Chloride Reduction"
Picatinny Arsenal Method. The following titra-
tion method developed at PicArsn as a culmina-
tion of many years work involving the Ti(III)'
titrant for nitro and nitrate species in general.
It was published in the open literature in Ref 8

Prepare, standardize, and store 0.2N tita-
nous chloride accdg to MIL-STD-286, Method
601.1. Similarly deal with 0.15N ferric Amm
sulfate, same MIL, Method 603.1. Prep a
buffer soln by adding 7ml of 30% NaOH per
25ml of a soln 1/1, wt/vol of Na acetate tri-
hydrate in w. Prep a 20% Amm diocyanate in-
dicator soln. For the titration flask use a ½-
liter flat-bottom boiling flask fitted with a S/T
24/40 female joint and a sealed in gas inlet
tube. Into a 1-liter volumetric flask weigh a
sample contg about 2.7g NGu. Add ½-liter of
hot, distd w with swirling to dissolve the sample.
Let cool to RT, then dilute to 1 liter with more
distd w and mix. Transfer 50ml of this soln to
the titration flask already contg 50ml of the
titanous soln and 25ml of the buffer soln de-
 aerated with CO_2 (the flow of which is not in-
terrupted until the analysis is complete). Mag-
netically stir the flask contents for 3 mins. Add
25ml of 1/1 HCl soln and 5ml of the indicator
soln. Titrate the excess titanous ion with the
standard ferric soln. Using the same reagents
and procedure run a blank. Then, %NGu =
1.7345 N(A–B)/W, where (A–B) represents the
corrected volume of ferric titrant, N is the ac-
tual normality of the latter, and W is the weight
of the sample, in g, represented by the aliquot
taken from the volumetric. The results are at
least as accurate, and probably more reliable
than those obtd by the nitrometer method de-
scribed in the JAN-N-494 Spec mentioned in
the previous section. The main advantage of
this reverse titration method is that the NGu
has much less opportunity to decompose in
the alkaline condition imposed by the buffer be-
fore being reduced by the Ti(III)

Note: In the method describing detn of TNT in
Dynamites, pp D1646-L to D1648-R of Vol 5 of
Encycl is given an illustration of "Apparatus
for storing and using titanous chloride solut".
There is also described on p D1646-L the me-
thod of prep of std 0.2N TiCl_3 soln from ri-
tanium hydride. The procedure was developed by Mr. N. Lisszt of Picatinny Arsenal.

Another, lengthier method involving transnitration of salicylic acid by the NGu is described in Ref. 4. It may not retain otherwise good accuracy on very finely divided NGu. Still other methods are described in the Refs., and Ref 7 compares some of the better known ones.

References for the Analysis of Nitroguanidine:
1) Davis (1943), pp 380-91

Nitroguanidine, Requirements and Tests of.
US Military Specification MIL-N-494A of March 1963 (superseding JAN-N-494 of 10 Sept, 1947), with Amendment 3 of Jan 31 1964 (superseding Amendments 1 and 2) and with Engineering Order from Picatinny Arsenal No EOPA-45940-S of 7 Dec 1966

1. SCOPE
1.1 Scope. This specification covers Nitroguanidine for use in the manuf of proplnts
1.2 Classification. NGu shall be of the following classes and types as specified (see 6.1 and 6.2):

- Type I – Minimum purity 98%
- Type II – Minimum purity 99%

Class 1 – Average particle diam 6.0 microns maximum & 3.4 microns minimum
(See Table II)

Class 2 – Average particle diam 3.3 microns maximum (See Table II)

2. APPLICABLE DOCUMENTS
2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein

STANDARDS
Military
MIL-STD-105 – Sampling Procedures and Tables for inspection by Attributes
MIL-STD-109 – Quality Assurance Tests and Definitions
MIL-STD-129 – Marking for Shipment and Storage
MIL-STD-1233 – Procedure for Determining Particle Size Distribution and Packing Density of Powdered Material
MIL-STD-1235 – Single and Multilevel Continuous Sampling Procedures and Tests for Inspection by Attributes

3. REQUIREMENTS
3.1 Material. NGU, as received, shall be a white, free flowing, crystalline powder, when tested as specified in 4.3
3.2 Properties. NGU shall be in accordance with the chemical properties specified in Table I, when tested in accordance with the applicable subparagraphs specified therein (See 6.4)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Type I, %</th>
<th>Type II, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Purity (assay)</td>
<td>98.0</td>
<td>–</td>
</tr>
<tr>
<td>Ash content</td>
<td>–</td>
<td>0.30</td>
</tr>
<tr>
<td>pH value</td>
<td>4.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Acidity (as sulfuric acid)</td>
<td>–</td>
<td>0.06</td>
</tr>
<tr>
<td>Total volatiles</td>
<td>–</td>
<td>0.25</td>
</tr>
<tr>
<td>Sulfates (as sodium sulfate)</td>
<td>–</td>
<td>0.20</td>
</tr>
<tr>
<td>Water insol impurities</td>
<td>–</td>
<td>0.20</td>
</tr>
</tbody>
</table>

3.3 Average particle size. NGU shall comply with the average particle size specified in Table II, when tested in accordance with 4.3.8

<table>
<thead>
<tr>
<th>Class</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.4</td>
<td>6.0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>3.3</td>
</tr>
</tbody>
</table>

3.4 Workmanship. The NGU and all containers shall be free from dirt, oil, grease, wood chips and other foreign material

4. QUALITY ASSURANCE PROVISIONS

4.1 General Quality Assurance Provisions (p 2)
4.1.1 Contractor Quality Assurance System (pp 2-3)
4.1.2 Submission of Product (p 3)
4.1.3 Government Verification (p 3)
4.1.3.1 Surveillance (pp 3-4)
4.1.3.2 Product Inspection (p 4)

4.2 Inspection Provisions (p 4)
4.2.1 Lot formation (p 4)

A lot shall consist of one or more batches of NGU, produced by one manufacturer in accordance with the same spec or its revision, under one continuous set of operating conditions. Each batch shall consist of that quantity of NGU that has been subjected to the same mixing process intended to make the final product homogeneous

4.2.2 Examination. Sampling plans and procedures for the following classification of defects shall be in accordance with Standard MIL-STD-105. Continuous sampling plans, in accordance with Standard MIL-STD-1235 may be used if approved by the procuring activity
4.2.3 Sampling by lot. A random sample of containers shall be selected from each lot in accordance with the following table:

<table>
<thead>
<tr>
<th>Lot Size</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 batch</td>
<td>8 containers</td>
</tr>
<tr>
<td>2 batches</td>
<td>12 containers</td>
</tr>
<tr>
<td>3 or more</td>
<td>16 containers</td>
</tr>
</tbody>
</table>

When lots are composed of 8 containers or less each container shall be sampled

4.2.3.1 Preparation of composite. Equal primary samples in sufficient quantity to total 16 oz shall be removed from each container. The individual primary samples shall then be combined in order to form a homogeneous composite sample of 16 oz and subjected to the tests specified in 4.3. If the composite sample fails to comply with any of the requirements specified, the lot shall be rejected

4.3 The following test methods and procedures shall be used:

4.3.1 Determination of purity. The purity shall be determined by either the nitrometer method or the alternative chromous chloride method

4.3.1.1 Nitrometer Method. The nitrometer method specified in Standard MIL-STD-286, method 209.3 shall be used as the standard method for purity except that a 3 g sample shall be crushed so that it will pass thru a US Standard No 100 sieve. A 1 g sample shall be dried in air at 46°C overnight and then placed in an oven for 1 hr at 100°C. The sample shall then be transferred to the nitrometer. The percent nitrogen
shall then be converted to percent NGu by the following formula:

\[
\text{Percent NGu} = \frac{7.430R}{W}
\]

where:  
\(R\) = reading of measuring tube  
\(W\) = sample weight  
7.430 = correction factor  

Note: Detailed description of nitrometer method with illustration is given in Vol 1 of Encycl, pp A373–R to A376–R.

4.3.1.2 Chromous Chloride Method  
4.3.1.2.1 Chromous Chloride (0.2N) Standardization.  
A 110g sample of hydrated chromous chloride shall be dissolved in about 500ml of distd w contd in a 2-liter volumetric flask. Fifty ml of concd HCl shall be added and diluted to the mark with distd w. After mixing, the soln shall be poured into a 4-liter bottle contg an excess of amalgamated zinc. The mix shall be allowed to stand overnight and maintained under this atmosphere at all times. A bright blue color indicates complete reduction of chromic ions (green) to chromous ions (blue). The chromous chloride solution shall be transferred to an automatic buret with a 2-liter reservoir.

4.3.1.2.2 Ferric Alum (0.15N) Standardization.  
The 0.15N Ferric Alum soln shall be prep’d as specified in Standard MIL-STD-286, method 603.1  
4.3.1.2.3 Procedure. An accurately weighed portion of approx 0.1g of sample shall be transferred to a 500ml titration flask. Twenty-five ml of distd w shall be added and shaken and heated until the sample is dissolved completely. The titration flask shall be placed with a magnetic stirrer and the contents shall be stirred for at least 10 mins. The air shall be swept out with a stream of carbon dioxide and the carbon dioxide atm shall be maintained throughout the detm. Exactly 50ml of 0.2N chromous chloride soln shall be added to the 500ml titration flask. The contents shall be stirred for 5 mins and 25ml of 15 percent HCl shall be added. Ten drops of 2% aq phenosafranin indicator shall be added and the excess chromous chloride shall be titrated with 0.15N ferric alum soln. The end point is a sharp color change from green to blood red. A blank detm using the same procedure and reagents but omitting the sample shall be conducted. The percentage of NGu shall be calcd according to the following equation:

\[
\text{Percent NGu} = \frac{1.735N(V_1 - V_2)}{W}
\]

where:  
\(V_1\) = ml of ferric alum used to titrate the total chromous chloride (blank)  
\(V_2\) = ml of ferric alum used to titrate the excess chromous chloride  
\(N\) = normality of ferric alun soln  
\(W\) = weight of sample in g used in the analysis

Note: Illustration of “Apparatus for Storing and Using Titanous Chloride Solution” is on p D1647 of Vol 5. On p D1646-L is stated that Mr N. Liszt developed a method of prep’n of TiCl₃ from titanous hydride.

4.3.2 Determination of ash content. The ash content shall be determined as specified in Standard MIL-STD-286, method 106.1

4.3.3 Determination of pH value. A portion of 5.0g of the sample, weighed to the nearest mg shall be transferred to an 8 oz bottle which has been previously heated to 80°C. A 200ml portion of freshly boiled distd w, which has been allowed to cool to 80°C, shall be added. The bottle and contents shall be immersed in a constant temp w bath, maintd at 80°C±2°C. The bottle shall be removed for shaking at 3-min intervals. As soon as the soln is complete, the bottle shall be removed and rapidly cooled to RT in cold running tap water. The pH of the soln shall be detd using a glass electrode pH meter. This soln shall be retained for the “Determination of Acidity” (See 4.3.4). Prior to the pH detm, the meter shall be calibrated using standard buffer solns, at pH 4.0 and pH 8.0.

4.3.4 Determination of acidity. The soln retained from the detm of the pH value shall be titrated with a 0.05N NaOH soln to a reading of 7.6 on the pH meter. A blank detm shall be conducted on an equal volume of distd w and the volume of NaOH used for the specimen shall be corrected. The percent acid present in the soln shall be calcd as sulfuric acid as follows:

\[
\text{Percent sulfuric acid} = \frac{4.9(A - B)N}{W}
\]

where:  
\(A\) = ml of NaOH soln used for titrating specimen  
\(B\) = ml of NaOH soln used for titrating blank  
\(N\) = normality of NaOH soln  
\(W\) = weight of specimen in g

4.3.5 Determination of total volatiles. A portion of the sample, approx 5.0g, weighed to the
nearest 0.1mg, shall be transferred to a tared Al dish (90mm in diam and 60mm deep) having a tightly fitting cover. The uncovered dish containing the specimen shall be heated for 2 hrs in an oven maintained at 100±2°C. At the end of this period the dish shall be covered, transferred to a desiccator until cool, and then weighed. The procedure of heating, cooling in a desiccator, and weighing shall be repeated at hourly intervals until 2 successive weighings do not differ by more than 0.2mg, or the specimen increases in weight. The percent total volatiles shall be calculated as follows:

\[
\text{Percent total volatiles} = \frac{(A-B) \times 100}{A}
\]

where: 
A = weight of specimen in g prior to heating
B = weight of specimen in g after heating

4.3.6 Determination of sulfates. A portion of the sample, approx. 5.00g, weighed to the nearest 0.1mg, shall be dissolved in 200ml of hot distd w contd in a 400-ml beaker. If necessary the soln shall be filtered thru a No 42 Whatman filter paper, or equal. The soln shall be made acid by the addn of 1 ml of concd HCl, which shall be followed by the addn of 1 ml of 10% Ba chloride soln. The soln shall be boiled for approx 5 mins and then allowed to stand, with occasional gentle stirrings, until cool. The soln shall then be allowed to stand for at least 10 hrs. At the end of this period, the soln shall be heated to boiling and filtered thru a previously ignited and tared Gooch crucible equipped with a fine asbestos mat. The ppt shall be washed with small portions of warm distd w, sucking each portion thru before adding the next. The last few washing shall be tested with 1% Ag nitrate soln to see that all chlorides have been removed. When free of chlorides the Gooch crucible shall be transferred to an oven maintained at 100±2°C. followed by 1 hour in a muffle furnace, mainatd at 600°C. The crucible shall then be transferred to a desiccator until cool, and weighed. The percent sulfate present in the specimen shall be calc'd to Na sulfate as follows:

\[
\text{Percent Na sulfate} = \frac{60.06A}{W}
\]

where: 
A = weight of residue in g
W = weight of specimen in g

4.3.7 Determination of water insoluble impurities. A portion of the sample of approx 10.0g, weighed to the nearest 0.1g shall be dissolved in 400ml of boiling distd w. The soln shall be filtered thru a tared Gooch crucible equipped with a fine asbestos mat. The residue shall be washed with a total of 100ml of boiling w, in 20ml portions, letting each portion go thru the crucible before adding the next. The crucible shall be transferred to an oven, mainatd at 105±5°C for 2 hrs, cooled in a desiccator and weighed. The gain in weight shall be calculated as percent water insol impurities as follows:

\[
\text{Percent water insol insol impurities} = \frac{(A-B) \times 100}{W}
\]

where: 
A = weight of crucible & residue in g
B = weight of crucible in g
W = weight of specimen in g

4.3.8 Average particle size. The average particle size shall be detd in accordance with MIL-STD-1233, method 100

Nitrosoguanidine (NsoGu), H₂N.C=NH.HNNO₃

mw 88.07, N 63.63%, OB to CO₂ at 54.5%; yel ndls, s p gr 1.52, explodes 161º; sl sol in cold w; sol in hot w; insol in alc & eth. May be prep'd by reducing NO₃ with Zn powder in dil sulfuric acid, or by treating a soln of Gu carbonate in dil'sulfuric with Na nitrite. NsoGu explodes on contact with concd sulfuric acid. It is sensitive to shock, friction, and burns, especially, with a very cool flame. The Fl value is 93% PA, the Pb block value 60% PA, heat of combustion (w liq) 2.22kcal/g and heat of expn 99kcal/g. Slowly dec in w, but may be commercially transported only with at least 10% w present. Manufd in the 1950's by Redel Inc, Anaheim Calif

Refs: 1) Beil 3, 124, (59) & [99] 2) T.L. Davis & A.J. Abrams, Proc Amer Acad ArtsSci 61, 444–57 (1926) & CA 21, 1968 (1927) 3) F. Olsen & F. Seavy, USP 2060522 (1937) & CA 31, 542 (1937) (Exp priming mixts contg NsoGu) 4) Bieie (1943), p 111 5) Davis (1943), pp 391–3 6) A. Okáč & J. Gmber, ChemListy 45, 49–51 (1951) & CA 45, 6541 (1951) ([Formation of NsoGu salts and their analytical evaluation]. (The Ag, Cu, and Ni salts were prep'd in hopes of their being useful for analysis of these metals as the system is very similar to glyoxime; the results were not favorable. The
Other Guanidine and Guanyl Derivatives

The remaining derivatives contg the guanidine, [\(\text{N(C(NH)N)}\)] and guanyl [\(\text{N(C(NH)}\)]) structural features have been somewhat arbitrarily alphabetized as (in order): derivatives of guanidine, guanidine derivatives, guanidino derivatives, and guanyl derivatives. Alkyl and nitroxyalkyl guanidines, following the pattern established earlier in this work, may be found under the alkyl, and hydroxyalkyl names, respectively, unless the particular alkyl radical was not previously entered.

1-(1,1-Dimethyl-2-nitroxyethyl)-3-nitroguanidine,
\(\text{O}_2\text{NCO.CH}_2\text{C}(\text{CH}_3)_2\text{NH.C(NH).NH.NO}_2\); mw 221.17, N 31.67%, OB to \(\text{CO}_2\) -76.0%; crysts, mp 112-14\(^\circ\)c (resolidities, and melts again at 175-7\(^\circ\)). Prepd by treating the unitrated compd with mixed acid at 0\(^\circ\).
Refs: 1) Beil, not found  2) L. Fishbein & J.A. Gallagher, JACS 76, 3217-29 (1954) & CA 49, 8990 (1955)

1-Methyleneamino-3-nitroguanidine
\(\text{O}_2\text{N.H.C(NH).NH.N.CH}_2\); mw 131.09, N 53.44%, OB -55.0%, crysts, mp 169\(^\circ\). Prepd as a deriv of formaldehyde by reacting the latter with aminonoritroguanidine.
Refs: 1) Beil, not found  2) W.F. Whitmore et al, JACS 57, 706-7 (1935) & CA 29, 3319 (1935)

1-Nitro-3(2,2,2-trifluoroethyl)guanidine,
\(\text{O}_2\text{N.NH.C(NH).NH.CH}_2\text{CF}_3\); mw 186.09, N 30.11%, OB -43.0% (to \(\text{CO}_2\), \(\text{CF}_2\text{O}, \text{HF}, \text{H}_2\text{O}, \text{N}_2\)); crysts, mp 147-8\(^\circ\). Prepd by reacting trifluoroethyamine with S-methyl isothioura in boiling w.
Refs: 1) Beil, not found  2) V. Milani et al, JACS 77, 2903 (1955) & CA 50, 3224 (1956)

Nonfluorodiaminomethylguanidine,
\(\text{F}_3\text{N.C(NF).NF.C(NF)}_2\text{F}\); mw 265.04, N 26.42%, FB +7.2% 'FB is analogous with OB, being applied hereafter to fluorinated compds wherein the F is not already on C; it is calculated in the same manner, the factor 1900/mw being used instead of 1600/mw); liq, bp ca 80\(^\circ\), mp below -130\(^\circ\), a 50/50 mixt of the cis and trans isomers. Prepd by fluorinating biguanide suflate with nitrogen diluted fluorine and a sodium-magnesium fluoride mixt at 0\(^\circ\). Proposed as an oxidizer for proplnts. Should be treated with extreme caution. May readily detonate into \(\text{CF}_4\) and \(\text{N}_2\). Do not let vapors contact mercury.
Refs: 1) Beil, not found  2) J.J. Hockstra, USP 3361815 (1968) & CA 68, 41777 (1968)

Octafluoroaminoguanidine,
\(\text{F}_3\text{N.C(NF).NF.CF}_2\text{NF}_2\); mw 232.04, N 24.14%, FB 0.0% (See preceding entry); colorless liq, bp 55\(^\circ\), mp below -130\(^\circ\), vap pres 124mm at 10\(^\circ\). Prepd by fluorinating cyanoguanidine with nitrogen diluted fluorine and a sodium-magnesium fluoride mixt at 0\(^\circ\). Proposed as an oxidizer for proplnts. Extremely expl and especially sensitive when undergoing solid-liquid phase transition. Best handled with \(\text{CF}_2\text{Cl}_2\) slush bath at -130 to -145\(^\circ\). Do not let vapors contact mercury.

Pentafluoroguanidine, \(\text{F}_3\text{N.C(NF).NF}_2\); mw 149.02, N 28.19%, FB +12.8% (See next to last entry); gas, bp -1 to 42\(^\circ\) (by extrapolation of vapor pressure data), sp gr 1.51 at 0\(^\circ\), mp -148 to -146\(^\circ\), dec rapidly at 243\(^\circ\). Prepd by fluorination (nitrogen diluted) of guanidine in the presence of sodium-magnesium fluoride mixt at 0\(^\circ\). Very shock and spark sensitive, extremely expl below the bp, may explode during liq-solid or solid-liq transition. Reacts with mercury, hydrolyzes rapidly at RT, but is stable in dry air. Best handled, in liq state, by use of a \(\text{CF}_2\text{Cl}_2\) slush bath just above the mp. Detonates forming \(\text{CF}_4\), \(\text{N}_2\), \(\text{F}_2\) with a heat of expl 1659cal/g; heat of formation is +23.0kcal/m.
Proposed as an oxidizer for propellants


Note: It is advisable for anyone contemplating prepn or use of pentafluoroanidine to examine all of these refs as a minimum

Tetrachloriodoguanidine, H, N, C(NH), NH-NCl; mw 327.79, N 12.80%, OB (to Cl2 and ½I2) –22.0%, om-yel prisms, mp 163°, sol in w (with sl dec), stable in dry air. Prepd by treating an HCl soln of Gu.HCl with chlorine and iodine
Refls: 1) Beil 3, [71] 2) F.D. Chattaway & F.L. Garson, JCS 125, 183–8 (1924) & CA 18, 986 (1924)

α-Tetrazol-5-yl-guanidine or 5-Guanylamino-tetrazole, [C(NH)(C(NH)NH-N-N=N)NH]; mw 127.11, N 77.15%; wh crysts, mp over 300°. Prepd by heating cyanamide with 5-aminotetrazole. Its expl props were not investigated
Refls: 1) Beil 26, [244] 2) R. Stollé et al, Ber 62, 1126 (1929)

α-Tetrazol-5-yl-guanidine Nitrate, [C(NH)(C(NH)NH-N-N=N)NH-HNO3]; mw 190.12, N 58.96%, OB –33.7%; wh crysts, explodes mildly on heating over 183°; sol in w; sl sol in alc. Prepd by adding nitric acid to an aq soln of cyanoanidine and hydrazoic acid

2,2,2-Trifluoroethylguanidine Nitrate, F3C.CH2.NH.C(NH)NH2.HNO3; mw 204.11, N 27.45%, OB –39.2% (to CO2, CF3.O, HF, H2O, N2); crysts, mp 134–6°. Prepd from the picrate (below) by treatment with nitric acid. Its expl props were not investigated
Refls: 1) Beil, not found 2) V. Milani et al, JACS 77, 2903 (1955) & CA 50, 3224 (1956)

2,2,2-Trifluoroethylguanidine Pircate, FaC.CH2.NH.C(NH)NH2.PA; mw 370.20, N 22.70%, OB –60.5% (to CO2, CF3.O, HF, H2O, N2); yel ndls, mp 183° (dec). Prepd from 1-nitro-3(2,2,2-trifluoroethyl)guanidine by hydrogenolysis followed by treatment with PA. Its expl props were not investigated
Refls: 1) Beil, not found 2) V. Milani et al, JACS 77, 2903 (1955) & CA 50, 3224 (1956)

Guanidinium 3,5-bis or di(nitramino)-as-triazole. See under Diamino-triazoles, Vol 5, p D1149-R

Guanidinium Dinitrocyanoethylide, [(H2.N)3C]([O2N]2CCN); mw 190.12, N 44.21%, OB –42.1%; crysts, mp 166–7°. Prepd by treating guanidine carbonate in aq alc with ethyl dinitrocyanoacetate at RT. Proposed as a proplnt ingredient
Refls: 1) Beil, not found 2) G.O. Parker, USP 3415867 (1968) & CA 70, 57206 (1969)

Guanidinium 1,1-dinitroethylide, [(H2.N)3C][O2N]2CCN; mw 179.14, N 39.11%, OB –58.1%; crysts, mp 97° (dec); sol in 5%, wt/wt, w at 20°. Prepd by reacting guanidine carbonate with K dinitroethylide in methanol
Refls: 1) Beil, not found 2) L. Zeldin & H. Shechter, JACS 79, 4708–16 (1957) & CA 52, 2735 (1958)
Guanidinium 5-dinitromethyltetrazolate, 
\[ (H_2N)_5C^+ \cdot (O_2N) - C.N:N.N.H^- \] mw 233.15, 
N 54.08%, OB –37.7%; yel crys, mp 164–4.5° (dec). Prepd by treating guanidine carbonate with 5-dinitromethyltetrazole. Its expl props were not investigated
Refs: 1) Beil, not found 2) F.J. Einberg, JOC 29 (7), 2021–24 (1964) & CA 61, 9490 (1964)

Guanidinium 3,5-dinitro-ac-4H-triazole; 
\[ [(H_2N)_3C]^+ . N(CNO :) N:N: C(NO_2)^- \] mw 218.13, 
N 51.40%, OB –36.7%; lt yel crys, mp 225–8° (dec). Prepd by treating guanidine carbonate with 3,5-dinitro-ac-4H-triazole in acet. The salt exhibits an impact sensitivity (2kg weight) of over 320cm, and is suggested for use as a press-loaded expl

Guanidinium Fulminuride, 
\[ (H_2N)_5C^+ \cdot NCC(NO_2) \cdot CO(NH^-) \cdot C; \cdot OH \cdot N \cdot H \cdot C \cdot N \cdot N \cdot N \cdot N \cdot H^- \] mw 188.15, 
N 44.68%, OB –76.6%; crys, mp 221–3° (dec). Prepd by treating guanidine hydrochloride with fulminic acid. Its expl props were not investigated

Guanidinium Hydrazine Decaborobyride, 
\[ [(H_2N)_3C]^+ \cdot [H_2B_9H_4 \cdot B_10H_{14}^-] \] mw 213.34, N 32.83%; crys. Prepd by adding decaborane, \( B_{10}H_{14} \) to an qq soln of guanidine and hydrazine, no props given. Compares unfavorably with the triminoguanidine analog as a fuel in rocket propels
Refs: 1) Beil, not found 2) E.A. Takacs, USP 3281219 (1966) & CA 66, 4569 (1967) (Hydrazinates and method of preparing them)

Guanidinium Hydrazinium Dihydrazilate, 
\[ (H_2N)_5C^+ \cdot H_2NNH^- (N_3) \cdot (N_3) \cdot (N_3) \cdot (N_3) \] mw 177.17, N 87.06%, OB –67.8%; crys. Prepd by heating a mixture of guanidine & hydrazine sulfates with sodium azide in methanol; no props given
Ref: Beil, not found

Guanidinium Hydrazoate or Guanidinium Azide, 
\[ [(H_2N)_5C]^+ \cdot N_3^- \] mw 147.14, N 85.71%, OB –70.7%; colorless prisms, mp 93.5° (46°, Ref 3); 159.2g
sol in 100g w at 20°; sol in qq alc & acet. Prepd by reacting with guanidine-HCl, AgN_3; with guanidine.H_2SO_4, Ba(N_3)_2; or with guanidine.H_2CO_3, HN_3. Deliquesces slowly when exposed to room air. Its expl props were not investigated

Guanidinium 5-nitroaminotetrazolate. See Vol 1, p A260-L

Guanidinium 5-(3-nitro-1-guanidino) tetrazolate, 
\[ [(H_2N)_5C]^+ \cdot H_2C(NH) \cdot N \cdot C \cdot (NH) \cdot C \cdot N \cdot N \cdot N \cdot N \cdot N \cdot N \cdot H^- \] mw 231.18, N 66.67%, OB –58.9%; wb tosettes, dec 240–2° in a hot bath. Prepd by mixing in qq alc: guanidine carbonate, 5-amino- tetrazolate, and 1-methyl-3-nitro-1-nitroso-guanidine. Suggested as a substitute for NGu in propless
Refs: 1) Beil, not found 2) J. Cohen et al, USP 3073731 (1963) & CA 58, 11164 (1963)

Guanidinium 3,5,7-trinitrotropolonate, 
\[ [(H_2N)_5C]^+ \cdot C; (O) \cdot C; (O^-) \cdot C \cdot (NO_2) \cdot CH \cdot (CNO_2) \] mw 361.23, N 34.90%, OB 59.8%; crys, mp 253° (dec). Prepd by heating guanidine sulfate in methanolic NaOH with a 1/1 complex of tropone and 3,5,7-trinitrotropolone. Its expl props were not investigated

N^2,4-Diguanidinomelamine Dihydrochloride, 
\[ (C \cdot NH \cdot Gu) \cdot N \cdot C \cdot (NH \cdot Gu) \cdot N \cdot C \cdot (NH \cdot H_2) \cdot N \cdot \cdot 2HCl \] mw 313.15, N 53.67%; crys, mp 320–2°. Prepd by reacting cyanoguanidine with phenol in HCl. Treatment with HNO_3 gives the dinitrate, mw 366.26, N 53.54%, OB –48.1%; mp over 360°; treatment with PA gives the dipero, mw 698.445, N 36.10%, OB –66.5%; mp 276–7°. Their expl props were not investigated
1,4-Dihydro-2-amino-4,4-dimethyl-6-guanidinomethylene Dinitrile,
\[ \text{C}_9\text{H}_8\text{N}_2\text{O}_4 \]
mw 309.24, N 40.78%, OB – 69.9%, crysts, mp 228–9°. Prep by treatment of the monopicrate, mp 231°, with nitric acid. The picrate had been prep by heating with AN at 180° 1,4-dihydro-2-amino-6-cyanamido-4,4-dimethyl-s-triazine, then adding ammonium picrate. Their expl props were not investigated


1,4-Dihydro-2,6-bis(guanidino)-1-guanyl-4-guanylimino-s-triazine. Trihydrochloride,
\[ \text{C}_9\text{H}_8\text{N}_2\text{O}_4 \]
mw 361.63, N 46.49%; crysts, mp over 360°. Prep by heating at 70° a mixt of dicyandiamide, cyanamide dihydrochloride, and phenol. Treatment with nitric or picric acids gave the corresponding nitrate or picrate (number of acid moieties not indicated), mp's over 360°. Their expl props were not investigated

Refs: 1) Beil, not found 2) K. Odo & E. Ichikawa, Jap P 71' 00031 (1971) & CA 74, 141885 (1971)

Guanidinoformylazide Hydrochloride (Guadin- din Carbonsuare Azid in Ger),
\[ \text{H}_2\text{N-C}:\text{(NH)}\text{C}(\text{O})\text{N}_3 \text{HCl} \]
mw 128.09, N 51.06%, OB – 53.5% (to \(1/2\)Cl_2); crysts, mp 157°; sol in w; insol in organics; explodes on heating. Prep by treating 1-amino-3-guanylurea dihydrochloride with \(\text{N}_2\text{O}_4\) in chl. Its expl props were not investigated

Refs: 1) Beil, 3, 130 2) J. Thiele & E. Uhlfelder, Ann 303, 112 (1898)

\(\text{N}^2\)-Guanidinomelamine Dihydrochloride,
\[ \text{C}_9\text{H}_8\text{N}_2\text{O}_4 \]
mw 256.10, N 49.22%; crysts, mp 298°. Prep by reacting cyanoguanidine with phenol in HCl. Treatment with nitric acid gives the dinitrile, mw 309.20, N 49.84%, OB – 38.8%, mp 257°; treatment with PA gives the monopicrate, mw 412.29, N 40.77%, OB – 73.8%, mp 290.5°. Their expl props were not investigated


\(\text{N}^2\text{,N}^2\)-Bis(guanyl)-\(\text{N},\text{N}^2\)-diaminoethylenediamine Dihydroxooate,
\[ \text{H}_2\text{N-C}(\text{NH})\text{C}(\text{NH})\text{N}_2\text{H}_2 \text{H}_2\text{O}_4 \]
mw 260.27, N 75.38%; crysts, mp 299–301° (dec.). Prep from the dibromide, mp 299–301°, by treatment with a basic ion exchange resin followed by treatment with \(\text{HN}_3\). The dibromide was prep from \(\text{N},\text{N}^2\)-diaminoethylenediamine and s-methyl isothioura hydrobromide in methanol at RT. The corresponding bis(diaminoguanyl) compd was found more useful as a propilt fuel

Refs: 1) Beil, not found 2) E.T. Niles et al, USP 3355491 (1967) & CA 68, 21557 (1968)

\(\text{N},\text{N}^2\)-Bis(guanyl)-trimethylenediamine or Methylene bis(guanidinomethane),
\[ \text{CH}_2\text{N-C}(\text{NH})\text{C}(\text{NH})\text{N}_2\text{H}_2 \text{H}_2\text{O}_4 \]
mw 158.21, N 53.16%; hygr crysts, mp 135°; sol in alc & w. Prep by treating methylene bis(aminomethane) with s-methyl isothioura sulfate. More recently isolated as the dipicrate salt by heating a mixt of cyanamide, methylene bis(aminomethane), and methylene bis (aminomethane p-toluene-sulfonate), then treating with PA; for the dipicrate: mw 616.42, N 27.27%, OB – 77.9%, mp 242°. Their expl props were not investigated

Guanyl Azide Derivatives and Salts. See Azidofomamide under Formamidine in Vol 6, pp F168-L to F169-R

Guanyldiazoguanyl Tetrazene. See Guanyl-nitrosaminoguanyl Tetrazene below

Guanylglycine. Same as Glycocyamine

Guanylguanidine. See Biguanide in Vol 2, p B114-L

Guanylydrazine. See Aminoguanidine in Vol 1, p A210-L

Guanylnitrosaminoguanyl Tetrazene or TETRACENE, also known as 4-Guanyl-1-(a-tetrazol-5-yl)tetrazene or Guanyldiazoguanyl Tetrazene. (It must not be confused with naphthacene which is also called Tetra-
cene); (Called Buzylene, rather than Tetra-
zene, in Ref 2, but same structure is meant; in recent literature the term "guanyl" has been replaced by "amidino", and then "carboxamidine"). Patinkin et al (Ref 11) claimed that the Tetrazole Hydrate, rather than the Nitrosaminoguanyl, was the actual structure, but both structures continue in use. Patinkin also prep a nitrate salt, mp 93–94° (dec) of the (claimed) Tetrazole structure-but with the 1 and 4 positions of the Tetrazene interchanged. Hofmann et al, the original preparers (Ref 2), also seemed to believe they had the Tetrazole and Nitrosaminoguanyl structure as separate compds. Its formula given in Davis (Ref 10) and AMCP-706-177 is

\[
\text{H}_2\text{N} = \text{C} \cdot \text{N} \cdot \text{H} \cdot \text{N} \cdot \text{N} \cdot \text{C} \cdot \text{N} \cdot \text{H} \cdot \text{N} \cdot \text{NO}\]

Its hydrate contns 3H$_2$O; mw of anhyd compd 188.15, N 74.47%, OB to CO$_2$ – 57.6%, OB to CO ca – 43%

A recent study of the structural analysis by single crystal methods (Refs 14 & 15) shows that Tetracene is the zwittterion (guanidinium) of 1-Amino-1-[(H-tetrazole-5-yl)azo]- guanidine Hydrate of structure:

in contrast to the structure previously as-
signed by Patinkin et al (Ref 11)

Tetracene exists as colorless or pale yel ndls; mp decomp ca 142° and explodes at 160° in 5 secs (vs 190° for MF); explodes in a flame w/o much noise but producing much bl smoke; apparent d only 0.45, but yields a pellet of d 1.05 when compressed at 3000 psi. It is practically insol in w, alc, eth, acet, benz, CCl$_4$ and ethylene di-
chloride; sol in dilute nitric acid; decomp by boiling w with formation of 2N$_2$ per mole; can easily be dead-pressed (Ref 10)

Tetracene was first prepd in 1910 by Hofmann et al (Ref 2) and then studied by them (Ref 3), but the most extensive studies were done by Rinkenbach & Burton (Ref 4) and results of their experiments are given by Davis (Ref 10) and in AMCP-706-177 (Ref 12)

Davis (Ref 10, p 449) describes in de-
tail a method of prepn starting with 35g of aminoguanidine bicarbonate, 2500ml distd w, 15.7g of glc AcOH and 27.6g of Na nitrite.

One lab method described in AMCP - 706-177 is not in the literature: Tetracene was prepd by dissolving 5g of aminoguanidine dinitrate in 30mm of distd w, cooling to 0°C and mixing with a soln 2-5g of Na nitrite in 15ml of w. While maintaining the temp at 10°, 0.5g of glc AcOH was added causing pptn of Tetracene. After allowing the slurry to stand overnight (or longer), the ppt was washed by decantation with several portions of w and then transferred to filter to be washed more thoroughly with w using suction. Then the product was dried in air at RT and transferrt for storage in a bottle provided either with a cork or rubber stopper
Another method of prep listed in AMCP 706-177 is from aminoguanidine sulfate and Na nitrite in distd w.

Following are expl props of Tetracene as given in Refs:

Brisance, by Sand Test. 0.4g initiated by No 6 cap crushed 28.0g sand, vs 23.4g by MF or 48.0g by TNT

Detonation Rate. not found

Explosion Temperature. 160° in 5 secs

Gas Volume. 1190cc/g

Heat of Explosion. 658cal/g

Heat Test at 100°. loss 23.2% in 1st 48 hrs, 3.4% in 2nd 48 hrs; no expln in 100 hrs

Hygroscopicity. only 0.77% gain at 30° & RH 90%

Impact Sensitivity. BM App, 2kg wr 7cm, vs 5cm for MF

Impact Sensitivity. PicArsnApp, 8 oz wt 8 inches, vs 9-10 inches for MF (Davis, p 449)

Initiating Efficiency. not efficient when used alone for initiating HE’s, but is as efficient as MF when initiated externally (Davis, p 450)

International Test at 75°. % loss in 48 hrs 0.5, vs 0.18 for MF

Loading. pressed

Power by Trauzl Test. 61% of TNT, vs 51% by MF

Sensitivity to Electrostatic Discharge, in joules. 0.010 for unconfined and 0.012 for confined

Sensitivity to Initiation. min detong chge 0.40g MF

Storage. wet

Uses: Can be used in detonators when initiated by another primary expl and functioning as an intermediate booster or when mixed with another primary expl to increase the sensitivity of the latter to flame or heat. Its mixture with LA was patented by Dynamit AG (Ref 8) for use in explosive rivets. Tetracene can also be used in primet caps where as little as 2% in the compn results in improved uniformity of percussion sensitivity.

The following Ger WWII priming mixts contg Tetracene are listed in Ref 11a, p Ger 197-L:

1. Priming Mixture No 30/40, used for rifle and pistol cartridges: Tetracene 3, Pb stroph.

nate 40, Ba nitrate 42, Ca silicide 10 & 0b dioxide 5%

II. Duplex-Cap Mixture for use in 20mm & 37mm, as well as in some larger shells, consisted of 0.30g of Pb azide 92.5 and Tetracene 7.5% pressed at 100kg/sq cm over 0.05g of unwaxed PETN pressed at 500kg/sq cm

III. Priming Mixtures used for pistol and rifle cartridges: Tetracene 2-3, Pb azide 30-35, Ba nitrate 40-45, Ca silicide 6-12, Pb peroxide 5-8 and Sb sulfide 6-9%

IV. Sinoxydsätze, listed on p Ger 179-R, were developed before WWII as replacement of MF mixts. They were claimed to be non-corrosive and did not erode barrels of firearms. Their compn was: Pb strophinate 25-55, Tetracene 1.2-5.0, Ba nitrate 25-45, Pb dioxide 5-10, Sb sulfide 0-10, Ca silicide 3-15 and powdered glass 0-5%

Refs: 1) Beil 3, (60), (103) & (240)
2) K.A. Hofmann et al, Ber 43, 682-83 & 1087-91 (1910)
3) K.A. Hofmann et al, Ber 44, 2496 (1911) & Ann 131 (1911)
4) W.W. Rinkenbach & O. Burton, ArmyOrdn 12, 120 (19319)
5) A. Stettbacher, Nitrocellulose 8, 141 (1936)
6) F. Grottanelli, Chim e Industria 18, 232 (1936)
7) G.B.L. Smith, ChemRev 25, 214 (1939) (Chemistry of aminoguanidine and related compds)
8) Dynamit AG, vorm Alfred Nobel & Co, BritP 528299 (1940) (Exp rivets using Tetracene)
9) Clift & Fedoroff, Vol 1 (1943), p G6 (Guanyl nitrosaminoguanyltetrazen)
10) Davis (1943), 446-50 (Tetracene)
11a) B.T. Fedoroff et al, PATR 2510 (1958), pp Ger 196-R & Ger 197-L: Tetracene (Tetrazen). The following Ger method of prep used during WWII is described. Utilizing the reactor provided with air agita., to a soln contg 4.0kg of Na nitrite in 60 liters of water and 1.5 liters of normal AcOH preheated to 50°, was added gradu and with air agita 40 liters of an aq soln of 5.3kg of aminoguanidine sulfate. The addn took 1 hr. After stirring the slurry for an addnl hr at 50° and for an hr at 20°, the reactor was tipped and the contents caught on the filter cloth made

Guanylnitrosaminoguanyltetrazene, TETRA-CENE or [1-(5-Tetrazolyl)-4-guanyltetrazene hydrate]. US Military Specification MIL-T-46938A (MU) (Ref 3) requirements and tests for material intended for use in military primer compositions.

Requirements:
3.3 Color and Appearance. Tetracene shall be white to light yellow and under microscope it shall appear as needle-shaped crystals.
3.4 Melting and Explosion Point: 130±2°
3.5 Granulation: 100% shall pass thru US No 45 sieve.
3.6 Specific Gravity: 1.65±0.05
3.7 Heavy Metals: must be absent.
3.8 Nitrogen Content: 74.5±1.0%

Test Methods and Procedures
4.4.1 Color and Appearance. Transfer a portion of about 10 g of the wet sample as received to a Büchner funnel and apply suction until the sample is almost dry. Spread the sample on a watch glass and place in a desiccator over concd sulfuric acid for 24 hours or in an oven at 70–75°C for at least 90 mins. Use this sample for all tests where a dry sample is required. Take four portions of about 0.5 mg each from different places in the sample and spread them over an area of about 2 cm square on a glass microscope slide. Observe the color of the material and then examine it under a microscope with reflected light using a magnification of 350 times.

4.4.2 Melting Point and Explosion Point. Weigh a capillary tube (1.5 to 2 mm in diam) and add a dry sample of Tetracene until about 0.5 to 1.0 mg is present. Put on a safety mask and dem the mp in a Vandenberg apparatus (Scientific Glass Apparatus Co Catalog 59, M-1945, Bloomfield, New Jersey). Heat the capillary tube in the enclosed airspace. Regulate the electrical heating system so that the rise in temp is one degree C every 3 mins. Observe the capillary tube thru the magnifying glass, which is part of the apparatus, and note when the substance melts and when the substance explodes.

4.4.3 Granulation. Transfer about 30 g of the wet sample, as received, to a Büchner funnel about seven cm in diam and apply suction for two mins. Weigh a 10 g portion of this damp sample and transfer it to a tared 3-inch No 45 US Standard sieve, which has been placed in a porcelain evaporating dish containing sufficient water to cover the wire portion of the sieve. Shake the sieve for a few minutes in such a manner that the Tetracene is below the surface of the water and any material passing thru the sieve is caught in the evaporating dish. When most of the Tetracene has passed thru the sieve, run a stream of water thru the sieve while brushing the residue lightly with a soft camel-hair brush. When no more material appears to pass thru the sieve, rinse that remaining on the sieve with 95% ethyl alcohol or reagent grade methanol, isopropanol, or mix thereof and dry the sieve and contents on a steam bath. Place the sieve in an oven at 70°–75°C for 30 mins, cool in a desiccator and weigh. Calculate the gain in weight as percent material retained on the No 45 sieve.

4.4.4 Specific Gravity. Weigh a dry 10 ml pycnometer. Fill it with water at 30°C and weigh again. Empty and dry pycnometer, add 0.2–0.4 g of dry Tetracene and weigh again. Add about 5 ml of kerosene and put under vacuum in a vacuum desiccator for a few minutes to remove air bubbles. Fill pycnometer with kerosene at 30°C and weigh. Calculate as follows:
Sp gr of Tetracene = \( \frac{W}{A - (B - C)} \) / \( S \)

where: 
- \( W \) = wt of sample
- \( A \) = wt of water contd in bottle when filled
- \( B \) = wt of bottle + Tetracene + kerosene
- \( C \) = wt of bottle + Tetracene
- \( S \) = sp gr of kerosene

4.4.5 Heavy Metals. To test for the presence of heavy metals, treat a 0.3g dry sample of Tetracene with 10ml of concd nitric acid and 5ml of concd sulfuric acid, evaporate to strong fumes until the soln is water white. Cool, dilute to 150ml with w and treat with hydrogen sulfide. No detectable ppt will be present.

4.4.6 Nitrogen Content. A dry sample of 2mg of Tetracene will be used for the nitrogen dem by the Micro-Dumas Method. Detailed instruction for performing this analysis can be found in standard tests on organic analysis, for example, “Quantitative Organic Micro-analysis” by A. Streyermark, obtainable from McGraw-Hill Book Co, Inc, 330 W 42nd St, New York, NY.

Tetracene can be identified by wetting a 0.25g sample with 5ml of 10% NaOH soln, and warming the mixt on a steam bath until it is dissolved. Note if odor of ammonia is present. Cool the soln, and add 1 ml of 5% Cu acetate soln. The appearance of a bright blue ppt indicates Tetracene (Ref 1, p 1346).

For a primer compn contg Ba nitrate, normal or basic Pb Stypnhate, Tetracene, Sb sulfide & Pb Azide, Tetracene content is detd by washing the residue from the stypnnhate dem several times with alc, aspirating, drying at 55-65° for 30 mins, cooling and reweighing. Using a jet of water, transfer the dry residue to a 125-ml beaker, add 25ml water, and boil for 5 mins. Filter thru the crucible previously used, wash the residue with boiling water and then alc. Aspirate, dry & reweigh as before. The loss in wt by water extraction represents Tetracene (Ref 1, p 1370).


**GuanylNitrosaminoguanylTetrazene or Tetracene Salts.** It forms numerous salts, most of which are explosive. Several of them are listed in Beil and other refs.

For example, Hofmann et al (Ref 2) prepd an Hg salt, black cubic crys, explode mildly on heating, violently on contact with silver nitrate and nitric acid; also a Silver salt, yel crys, very expl; the same salt is described in Davis (Ref 3, p 447).

Davis lists a Copper salt, a Nitrate, Perchlorate and Picrate (Ref 3, pp 469-70). He considers the perchlorate especially interesting. It dissolves in strong HCl and ether ppts the hydrochloride from the soln. Both the Perchlorate and the Picrate explode violently from heat and from shock.


**GuanylPentafluoradiaminomethane, H2N.C(=NH).CF.(NF2)2; mw 178.065, N 31.46%, OB -27.0% (to CO2, F2CO, 3HF, 2N2); yel visc oil, vap press 1 mm at 25°. Prep from a mixt of pentafluoro bisaminocrylonitile, ammonia, fluorotrichloromethane, and methyl ether at -110 to +25°. Probably a strong oxidizing agent; may be shock sensitive.**

Refs: 1) Beil, not found 2) R.J. Koshar, USP 3654341 (1972) & CA 76, 139957 (1972)

**GuanylTetrazolyl Tetrazene.** See GuanylNitrosaminoguanyl Tetracene or TETRACENE

**Guany lurea, Dicyandiamide or Carbamylguanidine and Derivatives.** See Vol 5, p D1217-R

**Trifluoroguanylfluoride or Tetrfluorotetramamidine, F2N.C(=NF).F; mw 116.02, N 24.14%, FB 0.0% (See under Pentafluoroguanidine); gas, bp ca -30°, dec at 208°. Prep by fluorination of guany lurea sulfate (nitrogen dilution).**
at -10°. The compd is assumed to be the sym isomer, shows ready hydrolysis in w, is shock sensitive, and should be considered a powerful expl and oxidizing agent


Guar Gum or Guar Flour. Light-grey pdr dispensible in hot or cold w; has 5–8 times the thickening power of starch. It is the ground endospore of Cyanopsis teinagonoloba, cultivated in Pakistan as livestock feed. The water-sol portion of the flour (85%) is called guaran and consists of 35 parts galactose, 63 mannose and 5–7 protein. Used as a binding agent in expl comps; also in paper manuf, atomic metal processing, etc

As examples of expls contg guar gum one may cite Blasting Explosive as listed as Ref 117 on p D1658-R of Encycl, Vol 5. The gum is used with borax as its cross-linking agent. Another example is explosive slurry contg 1% guar gum listed in Ref 171, p D1662-R. The slurred Blasting Explos contg 1.9% guar gum is listed in Ref 178 on p D1663, Expl compn listed as Ref 214 on p D1666-R contd 1% guar gum. Brit safety expl listed as Ref 223 on p D1667-R contd 1% guar gum. Expl compn contg 1% guar gum is listed as Ref 277 on p D1674-L and many other compns some of them contg less than 1% guar gum (Other gums are described under GUM)

Gudron. Russ for Tar or Pitch

Guerilla Incendiary Mixture. According to Stettbacher (Ref) the following expl incendiary mixt was used by guerillas during WWII. It was prepd by dissolving about 30.5 parts of yellow phosphorus in some carbon disulfide and adding to it about 62.5 parts of powderd KClO₄. When this liquid was poured on some object (such as tank), self-ignition and even explosion took place just as soon as the carbon disulfide evaporated

Ref: A. Stettbacher, Protor 40, 160(1944)

Guerilla Warfare. This term refers to military operations conducted by informal forces which operate within territory nominally controlled by the enemy and which have no permanent bases or other permanently defended territory. Guerilla warfare is usually thought of as small-scale and independent operations, as in insurgency or revolutionary war situations. Guerilla warfare can also be a secondary adjunct to ordinary military operations, as in the case of the Palestinian commandos

Guerilla warfare is based on temporary concentrations on the offensive, followed by dispersion on the defensive. This may involve going clandestine (using concealment by natural cover, eg forests) or covert (disguise by assuming a civilian cover). The actual tactics are conventional rule-book ones for an inferior force: avoidance of battle, ambushes, and the slow erosion of superior forces by repeated attacks on outposts & supply lines. The key factor in guerilla warfare is the source of supplies, since the force lacks either a home territory or supply lines to it. Where subversion does not work and where the home base does not exist or cannot overcome the logistic problem, guerillas cannot survive as effective fighting forces because they have to acquire food supplies by using force against the local population, which is politically inefficient & tactically inefficient


NOTE: See also the following books on Guerrilla Warfare:
9) Staff, "Studies in Guerrilla Warfare", United States Naval Institute, George Banta Co Inc, Mdnasha, Wis (1962)

Guhr, Kieselguhr, Diatomite, Diatomaceous Earth (DE) or Infusorial Earth. A soft earthy rock composed of siliceous skeletons of small aquatic plants called “diatoms”. Light-colored solid resembling chalk or dried clay in appearance; sp gr 1.9–2.35 (true), 0.15–0.45 (apparent); insol in acids except HF; sol in strong alkalies; able to absorb up to 4 times its own wt in water or in NG. Used in filtration, clarifying, and decolorizing of liquids and (in some countries except USA) as an absorbent (“dope”) for NG in so-called Guhrdynamite (See under DYNAMITE in Vol 5, p D1595-L)

3) Kirk & Othmer 7 (1965), pp 53–63 (Diatomite)

Guggenheim Process. A process for the manuf of Na nitrate from Chilean nitrate ore, caliche, in which heat is efficiently utilized and handling costs are kept to a minimum

Guhrdynamite or Dynamit No 1, also known as Nobel's Safety Powder. Explosive consisting of NG 75 absorbed on kieselguhr 25%, invented by Alfred Nobel and patented in England in 1867

Its history is discussed in Vol 5 of Encycl, pp D1588-R & D1589-L and prep & props on pp D1595-L to D1596-R

Guhrhellhoffit. Ger expl prepd ca 1880 by absorbing with kieselguhr a mixt of Nitrobenzene and fuming nitric acid (See also under Hellhoffit in Vol 7 of Encycl)
Refs: 1) Colver (1918), 143
2) PATR 2510 (1958), Ger 81-R

Guichard’s Balance Method for Determination of Stability. The stability of an expl may be judged by the rate at which it loses weight at elevated temps. In the regular procedures, a weighed sample is heated in an oven for a definite length of time, then removed, cooled and reweighed. This gives the loss in weight for a definite time and temp. If it is desired to prep a curve giving the relation between time, loss of wt and temp, heating has to be repeated for another time interval, the sample reweighed, and so on. In order to eliminate the necessity of repeatedly removing the sample from the oven for weighing, Prof M. Guichard at Sorbonne, Paris, France (Refs 1 & 2) constructed a balance with hydrostatic compensation
which permitted the continuous weighing of the sample without removing it from the oven. The temp of the oven can either be kept constant or set to rise at a desired rate per unit of time. This apparatus is described in detail in Ref 3.

Instead of a balance with hydrostatic compensation, a chainomatic balance may be used, but the rest of the apparatus should be the same as described by Guichard.

Refs: 1) M. Guichard, Bull Soc Chim (France) 39, 1113 (1926) and 3, 115 (1936)
2) Ibid, Ann de Chim 9, 324 (1938)

**GUIDANCE SYSTEMS**

**Guidance System of a Missile** (See also under GUIDED MISSILES). Accord to Locke (Ref 4, p 4), it may be defined as a group of components which measures the position of a guided missile with respect to its target and causes changes in the flight path as required. Some of the system elements may be external to the missile located either at the launching site, or en route to the target or on the target itself.

Normally the guidance includes: sensing, computing, directing, stabilizing and servo-control components.

Accord to Gatland (Ref 2, pp 13–16), the post WWII American and European guidance systems may be subdivided into:

A. Beam Rider Control System. With this system a ground radar tracks the target (such as an airplane), while the attacking missile climbs within the cone of a radar beam towards the target. The system is usually considered in conjunction with a self-homing device which monitors the gyropilot of missile so that in the final stage of an attack the missile is self-directing. This system is not as good as the B B. Command Guidance System. With this system one radar tracks the target, while the other tracks the missile. Each radar feeds data into a computer, whereby steering commands are transmitted to the missile.

Some of the current American guidance systems may be considered as modifications and improvements of German systems developed before and during WWII (See under GUIDED MISSILES, Historical). For this reason we are including below a brief description of German systems, as given in PATR 2510 (Ref 6, pp Ger 83 & Ger 84 and in Refs 1, 3 & 4).

A. Acoustic Homing Devices. These utilized the sound produced by airplane engines as a guiding medium. Two such devices were developed and were intended for guiding the X-4 missile. Both systems received the sounds from two separate entrance ports and determined the direction of the target by comparing the phase of the incident sound front. Phase comparison circuits were used to command the missile to maneuver so that the phase angles became equal. This made the missile point directly at the target. The principal advantage of the acoustic homing missile was the impossibility of jamming its receivers (such as is done with radio controlled guidance systems (Ref 4, pp 602–5).

Accord to Ref 3, pp 216–19 & 229, the original acoustic homing system was called Kranich and the later version Pudel. The Pudel fuze was not sufficiently developed to be used in combat, but the Kranich fuze was. The Kranich consisted of a light diaphragm-actuated mechanism which responded to the sound of airplane propellers at a range of 15 meters. It was constructed on the same principle as the Pudel fuze. It was planned to install the Kranich system on some Rheintochter missiles.
B. Ballistic Guidance System, also called Inertial-Gravitation Guidance System. This was essentially similar to a long-range gunfire guidance. As with a gun for surface fire, a missile such as a V-2 (A-4) was aimed in the desired direction in azimuth and pointed at such a precalculated elevation angle that the projectile would fall to the surface at the correct target range. The V-2 was directed in heading during its burning period by four external and four internal vanes. The external vanes, located in the outer trailing edge of each large fin, created aerodynamic moments, whereas the internal vanes, made of carbon and located to the rear of the motor, varied the direction of thrust of the motor. For control in azimuth, the external and internal vanes were interlocked but they were so connected as to permit separate control in pitch. (Ref 4, pp 36-8 & 583-4)

Accdg to Ref 3, p 211, the V-2 missile was regulated in flight by fins which were positioned by hydraulic servo-mechanisms controlled by an elaborate intelligence system. This system consisted of:

a) Two gyroscopes to provide stability about the three axes of the missile
b) Radio (optional) to provide azimuth control by flying on a beam
c) Radio or integrating accelerometer for tuning the motor at a specific velocity, to provide range control
d) Time switch control to bend the missile over toward the target after it was launched vertically

After elaborate prepts requiring much time, personnel and equipment, the V-2 was fired vertically from a metallic launcher. A few seconds after the V-2 was in the air, the time switch control caused the missile to bend gradually over in the direction of the target. After 1 min of flight, the motor was turned off leaving the missile at about a 45° angle and having a velocity of about 3400 mph. For the remainder of the flight, the V-2 followed the trajectory of a free body in space reaching a maximum height of about 50 miles before returning to the surface of the earth some 200 miles from the launching site with a velocity of approx 1800 mph causing the warhead and any remaining fuel to explode.

C. Infrared (IR) Guidance System consisted essentially of a concave mirror directed toward a target emitting the infrared radiation. A rotating disc and a photocell connected by a wire to a mechanism regulated the right-left and up-down movements of the missile. A schematic view of such device is given on p 11 of Ref 1 and a general description on detection of the infrared is given in Chapter 5 of Ref 4. One of the IR homing devices was used on the Rhein- tochter, R-3 (Ref 3, p 229), while another IR device, called Madrid, was installed on the Enzian, E-4 missile (Ref 3, p 232).

D. Magnetic-Ballistic Guidance System, such as used in the V-1 (FZG-76) missile, called also a "Buzz Bomb", was simple, rugged and reasonably reliable. In this system the azimuth was controlled by a magnetic compass, the altitude by a barometric altimeter and the range by an air mileage measuring unit. Prior to launching the missile, the devices were manually set for the desired course, altitude and range. The compass was linked to the directional gyroscope, whereas the altimeter acted directly on the elevator control system. All of the controls and amplifiers were pneumatic and the high-pressure air was stored in two tanks. When the predetermined range was reached in flight, the warhead was actuated and armed. The controls were then locked causing the missile to dive. The accuracy of the terminal portion of the flight depended upon the ballistics of the missile. (Ref 4, pp 35-36, 327-8 & 335-7). For more information on guidance systems for V-1 see Ref 3, pp 207-9. Some V-1 bombs were equipped with a one-tube radio transmitter for enabling the launching crew to follow the flights with direction finding equipment in order to obtain plotting and wind data (Ref 3, p 209).

E. Radar Guidance System or Radio Detection and Guidance System was not sufficiently developed to be used on a wide scale. Radar tracking of the target was used for guiding the Wasserfall and Rheintochter missiles (Ref 3, p 227 and Ref 4, p 41).

F. Radio Controlled Guidance Systems con-
sisted essentially of a radio receiver (located in a missile), a missile tracker and a radio transmitter (located near a missile launcher) for conveying the command to the receiver. This system was used in the majority of German guided missiles.

He 293A was the first German radio controlled bomb. It was made in 1940 by Henschel, by equipping with radio control devices, the non-guided glide bomb designed in 1939 by the Gustav Schwartz Propellerwerke (Ref 2, p 202)

The following German radio controlled systems are listed or briefly described in Refs 3 & 4:

a) **Burgund** system consisted of an optical (visual) missile tracker, Knüppel, with a joy stick control, a radio receiver, **Strassburg** and a transmitter, **Kehl**. The Strassburg-Kehl combination was used in the PX-1400 glider bomb, Schmetterling (Hs 117) rocket, Wasserfall (C-2) rocket and Great Enzian rocket (Ref 3, pp 215-16, 223 & 232 and Ref 4, pp 38-43)

As a substitute for the Strassburg-Kehl command link, the Kran-Brigg system was developed late in WWII (Ref 4, p 41)

b) **Elsass** system was similar in operation to the Burgund's, except that radar tracking of the target replaced the optical tracking. It was proposed for use with the Rheintochter 3 and some other missiles (Ref 3, p 227 and Ref 4, p 41)

c) **Sonne** radial guidance system was based on the method which a navigator of a ship uses to determine its position by plotting the reverse bearings obtd from the radio transmitters of two known locations. The device Sonne was more complicated than the systems used in ship navigation. A brief description of the principles applied in the Sonne is given in Ref 4, p 595

d) **Friesicke & Höpner** radio receiver, first mounted on a Hs 293 missile proved to be too heavy and complicated for use. It was replaced by the Storo radio receiver (Ref 3, p 199)

e) **Stuttgart** radio telemetering system was tested on the Feuerlilie F-55 missile (Ref 3, p 226)

f) **Strassfurt** radio control system designed by the Rundfunk Co was planned to be used in the Enzian missiles (Ref 3, p 232)

g) **Kagge** radio control system designed by the Telefunken Co was intended for use in Enzian missiles (Ref 3, p 232)

**G. Wire Controlled Guidance Systems.** Owing to the fact that radio command guidance systems were susceptible to electronic countermeasures (jamming), a control by wires was developed. The system was installed in the X-4 air-to-air missile and was planned to be installed on the X-7 surface-to-air missile and some Henschel missiles (Ref 3, pp 205 & 216-16 and Ref 4, p 41). The wire links system was effective over short distances without fear of enemy countermeasures (See also Ref 3, p 217)

Since the wire method of control restricted the maneuverability of launching planes and required that they remain in the vicinity of missiles, thus exposing themselves to the weapons of enemy's bombers, the wire control method was replaced in the latter model of the X-4 by an acoustic homing device Kranich. With the latter device the parent plane could execute an evasive maneuver the moment the missile was launched and then withdraw itself beyond the range of enemy bombers' weapons (Ref 3, p 216)

The following varieties of wire control links systems are briefly described in Ref 4, pp 41-2:

a) **Dortmund-Duisburg** system consisted of an optical joy-stick control unit, a transmitting unit, two spools with wires (as described above) and a receiver located in the fuselage of X-4. The transmitting equipment consisted of an oscillator (operated by pulses from the joy-stick control) and an audio power amplifier which transmitted two audio-frequency signals thru wires to the receiving set in the missile. The audio signals were demodulated by the receiver to operate two polarized relays, one for pitch and another for yaw control

b) **Doren-Detmold** wire command link was a simple direct-current device which employed no vacuum tubes. The signals were transmitted to the receiver, which consisted of three relays. The 1st relay was sensitive to the polarity of the direct current signals (pitch control), the 2nd relay was sensitive to the amplitude of the signal (yaw control)
and the 3rd served to disconnect the other two when the transmitting wires were broken. In this case, the missile continued to follow the course of the last command received. The wires were the same as with the Dortmund-Duisburg system except that insulation was not removed, since it was essential in this system to keep the resistance of wires constant

**Note:** In all wire control systems, the fall of wire to the earth proved to be a nuisance and a hazard


**Note:** More recent refs on "Guidance" are given under "GUIDED MISSILE"; Addnl Refs

**Guided Aircraft Missile (GAM).** A guided missile designed for launching from an aircraft in flight

**Ref:** GlossaryOrdn (1959), 141-L

**Guided Aircraft Rocket (GAR).** A rocket-powered guided missile designed to be launched from an aircraft in flight

**Ref:** GlossaryOrdn (1959), 141-L

**Guided Bomb.** An aerial bomb guided during its drop in range or azimuth, or in both

**Ref:** GlossaryOrdn (1959), 43-L (Bomb, guided)

**GUIDED MISSILES.** (Gesteuertes Geschosa in Ger; Projectile guidé in Fr; Oopravlëyemyi snarïad in Russ; Missile telecomandato in Ital; Proiettili guidato, in Ital)

**History.** Historically, guided missiles, also called directed missiles, were first used by Germans during WWII. They ranged from simple standard type aerial bombs, fitted with special equipment which permitted them to be directed thru a portion of their flight path, to V-1 and V-2 missiles. Americans, British and Russians used also during WWII some guided missiles, but none of them ever approached the qualities of German V-1 & V-2. After capitulation of Germany, all her enemies rushed to learn as many secrets on guided missiles as possible. Fortunately, "lion's share" came to Americans and Britishers, because Germans fearing Russian invasion transferred, near the end of the war, most of their equipment, including everything from Peenemünde, from east to west, and key personnel, such as Dr Werner von Braun and W. Dornberger. Since then, the Americans and British improved on German models and created their own. They are better equipped now than Germans were before and during WWII

**General Description of Guided Missile.** An unmanned, self-propelled vehicle capable of having its trajectory changed in flight to correct its path for errors or target motion. Generally, guided missiles are used for military purposes and travel above the earth's surface. The term "guided" is reserved for aerodynamic missiles and does not include naval torpedoes, which maintain a preset course, or ballistic missiles (See Vol 2 of Encycl, p B6-L & R), which follow a ballistic trajectory after thrust is terminated

**Classification.** Missiles are commonly classified by their launch and target environments, as well as by popular names. Other methods of classifying guided missiles are by trajectory, speed (subsonic, sonic or supersonic), propulsion (air breathers, usually jets or rockets), guidance (command, inertial or homing), payload (such as nuclear, high explosive, or electronic jammer), and purpose (strategic or tactical, offensive or defensive)

**Guidance Systems.** (See also previous item: Guided System of a Missile). There are several types of guidance systems: (1) They carry, in the missile, devices which enable
them to compute where they are in relation to a precalculated course. This requires extremely accurate mechanical and electronic devices built into the missile. Such a system is known as "preset" and is suited generally to the surface-to-surface missile where the target is fixed. 2) Another means is to control the missile from the ground by knowing precisely where it is at all times and predict where the target will be. With this missile, it is possible to send electronic commands by radio, or radar techniques to the missile to enable it to correct its course so as to hit the target. 3) A missile may be designed to fly automatically in an electromagnetic beam while the beam is pointed onto the target. This is the beam-rider method used principally in the field of anti-aircraft defense. 4) A navigational system causes the missile to orient itself automatically with respect to stars or other known reference points, such as radar stations, and steer itself along the prescribed course. 5) The homing system uses missile borne devices to identify the target by heat, light, radar, sound, or other means and correct its flight path to hit the target. Homing is applicable against nearby targets or for final corrections at the terminal end of a long trajectory. Some missiles, particularly the long range ones are guided by a combination of two or more of these systems. Applications and Advantages. Since WWII, all modern military forces have been reshaped to some degree around guided missiles. The type to receive the greatest emphasis during the early period of guided missile development was the surface-to-air missile (SAM). These are anti-aircraft missiles designed to combat the high performance aircraft and missiles. Within this category are mobile systems, naval ship installations, and fixed land based installations. Antibalistic missile SAM systems have an important place in the strategic nuclear force of Russia. Guided missiles offer marked advantages in air-to-air use over conventional guns and unguided rockets. The air-to-air guided missile permits effective attack from much greater ranges and nearly every angle than conventional weapons. The guided missile also provides increased accuracy of delivery while reducing the risk to the attacking aircraft. Surface-to-surface missiles supplement or, in many applications, entirely displace conventional artillery for attacking fixed or moving battlefield or naval targets. The missile can carry a much greater payload to a greater range and with greater accuracy.

Guided Missiles, American. The following is a listing of various American missiles according to their type: Air-to-air missiles (AAM): Falcon, Sidewinder/Sparrow; Air-to-surface missiles (ASM): Bullpup, Hound Dog, Shrike, Walleye; Surface-to-air missiles (SAM): Chaparral, Hawk, Nike-Hercules, Redeye, Talos/Terrier/Tartar; Surface-to-surface missiles (SSM): Subroc, Shillelagh. There are: Surface-to-underwater (SUM); Underwater-to-air (UAM); Underwater-to-surface (USM); and Underwater-to-underwater (UUM) (Ref 6).

Missiles Developed by Other Countries. (AAM): Matra RS30 (France); Firestreak/Red Top (British); Alkali/Anat/Ash/Stoll/Awl (Russia); (ASM): Nord AS20/AS30 (France); Martel (British-French); Robor R604 (Sweden); Blue Steel (British); Kan garoo/Kipper/Kitchen/Kennel (Russia); (SAM): Bloodhound/Tiger cat (British); Thunderbird (British); Seacat/Seaslug (British); Guideline (SA-2) (Russia); Goa (SA-3) (Russia); Galosh (Russia); (SSM): Ikara (Australia); Malafon (France); Entac (France); SS/11/SS-12 (France); Cobra (German); KAM-3D (Japan), Bantam (Sweden); Mosquito (Swiss), Vigilant (British); Sagger/Swatter/ Snappet and Styx (Russia); (See also "Ballistic Missiles" in Vol 2 of Encycl, p B86)


Addnl Refs: A) B.H. Liddell Hart, "The
Guided Missile, Antitank. An A/T missile whose path is controlled by a combination of optical sighting and command signals from an automatic computer through multiple wire command links. It may also contain an IR homing device for final range correction. It is designed to be launched from any type of vehicle or ground emplacement. This excludes items whose trajectory cannot be altered in flight.

Ref: GlossaryOrdzn (1959), 141-L
Guided Missiles, German of WWII. Beginning in 1938 several successful guided missiles were developed in Germany, mostly at Peenemünde and Volkenrode (See also History, under GUIDED MISSILES).

One of the first successful missiles was Rheinbote (Rheinmessenger). It was described by Ross (Ref 2).

Other successful missiles are listed in Ref 5, p Ger 85 and briefly described in Refs indicated here. See also illustrations shown on p Ger 85 of Ref 5, reproduced here.

Other successful guided missiles were:

a) Schmetterling (Butterfly), also known as the Hs-117 (Ref 2, p 35)

Note: Hs is an abbr for Henschel, the name of the builder.

b) Wasserfall (Waterfall) (Ref 2, p 37)

c) Rheintochter (Daughter of the Rhein) series such as Rheintochter I, II & III (Ref 2, p 40)

d) Enzian (Gentian, a species of blue flower) series, ranging from E-1 to E-5 (Ref 2, p 43 & Ref 1, p 99)

e) Feuerlilie (Fire Lilly) series, of which the Hecht (pike) was one of the first successful. T-Stoff and Z-Stoff were used in it. The Hecht was succeeded by the Feuerlilie F-25. The last of the series was the F-55, used only for research (Ref 2, pp 45-47, Ref 1, pp 95-96)

f) Bachem BP-20 Natter (Viper) (Ref 2, p 47)

g) Ruhrstahl (Steel of the Ruhr) series ran from X-1 to X-7, of which the X-4 was the most important (Ref 2, p 50 & Ref 1, pp 90-2)

h) Hs (Henschel, the name of builder) series, including the previously mentioned Hs-117 (Schmetterling), as well as Hs-117H, Hs-293, Hs-294, Hs-295, Hs-296 & Hs-298 (Ref 2, pp 52-54 & 56-60, Ref 1, pp 92-3)

i) Fritz X (FX-1400), a glide bomb (Ref 2, p 55)

j) Beethoven Apparatus - an odd looking guided missile (Ref 2, pp 61-62)

k) BV-246 (Ref 2, p 63)

l) V-2, is briefly described separately under V-2 and below. It could be launched as a guided missile (Ref 5, p Ger 213)

m) Antipodal Bomber (Ref 3, pp 57-58)

n) Toifun, a biquadratic rocket (Ref 4, p 223)

These rockets were fired against England, ships which could withstand explosives and compressed air as air cushion. The engines used were 1,920-2,070 lbs, propelled by a pulse of 470 lbs. The rocket is on display at the German War Museum, London. The body of the V-1 is a projectile, designed for a speed of 2,000 miles per hour, with a range of 2,000 miles. It could be launched from a coastal battery with a range of 2,000 miles.

The official German weapon of the V-1 is the V-1 flying bomb. The German designation was VZ.G-76 and the British V-1 (V-1 of the English Channel Fleet) (V-1 of the Vergeingkoppelle Einf).
Guided Missile, German V-2 oder Vergeltungswaffe Zwei (V-2 or Revenge Weapon Two). The official German designation was A-4. V-2 was a rocket provided with 4 stabilizing fins and control radio. It could fly with a speed up to 3600 mph to a distance up to 220 miles and at altitudes up to 50–60 miles. The body of the rocket was cylindrical in shape with a nose tapering to a sharp point. The largest diameter was about 5 ft and the overall length 46 ft. Fully loaded it weighed about 14 tons, which included 9 tons of fuel supply and about 1 ton of special explosive that could withstand high temps in the warhead. The first of these rockets was fired against England in Sept 1944. A total of 115 V-2 rockets were fired up to April 2, 1945, and they caused considerable damage especially in London and vicinity.

Table 62 gives some additional information on V-2, as taken from the book of Gatland (Ref 3, p XVII).

Table 62

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Metric</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>14 m</td>
<td>46'</td>
</tr>
<tr>
<td>Diameter of body</td>
<td>1.65 m</td>
<td>5'6&quot;</td>
</tr>
<tr>
<td>Take-off weight</td>
<td>12,900 kg</td>
<td>28,400 lb</td>
</tr>
<tr>
<td>Payload</td>
<td>1000 kg</td>
<td>2205 lb</td>
</tr>
<tr>
<td>High explosive carried</td>
<td>750 kg</td>
<td>1654 lb</td>
</tr>
<tr>
<td>Alcohol (Contg 25% water)</td>
<td>3965 kg</td>
<td>8740 lb</td>
</tr>
<tr>
<td>Liquid oxygen</td>
<td>4970 kg</td>
<td>10,957 lb</td>
</tr>
<tr>
<td>Thrust at take-off</td>
<td>25,000 kg</td>
<td>55,100 lb</td>
</tr>
<tr>
<td>Thrust gain near Brennfluss</td>
<td>4200 kg</td>
<td>9,320 lb</td>
</tr>
<tr>
<td>Fuel consumption per second</td>
<td>127 kg</td>
<td>280 lb</td>
</tr>
<tr>
<td>Alcohol / oxygen ratio in mixture</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Maximum burning time</td>
<td>~2700°C</td>
<td>~4890°F</td>
</tr>
<tr>
<td>Temp in motor</td>
<td>15.43 atm</td>
<td>227 psi</td>
</tr>
<tr>
<td>Pressure in motor</td>
<td>15.43 atm</td>
<td>227 psi</td>
</tr>
<tr>
<td>Nozzle expansion ratio</td>
<td>15.43:0.85</td>
<td></td>
</tr>
<tr>
<td>Exhaust velocity</td>
<td>2050 m/sec</td>
<td>6725 ft/sec</td>
</tr>
</tbody>
</table>

Refs: Same as under Guided Missiles, German of WWII and W. Domberger, “V-2”, The Viking Press, NY (1954), 93–8

Note: The description given here is from PATR 2510 (1958), p 213

Note: Its predecessor V-1 (Vergeltungswaffe Eins), known as “Buzz Bomb” was not guided. It is described in PATR 2510 (1958), p Ger 213-L with Fig on p Ger 214
Guided Missile Launcher. A device or installation from which a self-propelled missile is launched. It usually incorporates a rail, tube, wooden or steel frames, etc for giving the missile initial guidance. Some of the launchers are the same as used for launching rockets. Germans developed and used during WWII many types of launchers and nearly all of them are described in PATR 2510 (1958), p Ger 164 under Rocket Launcher or Projector with numerous illustrations on p Ger 165. Some of them are shown in the Figs included here.

For more info on guided missile launchers see Ref 2 and books on guided missiles and under Launchers

Refs: 1) Glossary Ord (1959), 168-L

Note: Illustrations of NIKE and CORPORAL launchers used by the US Armed Forces are given on pp 173-74 of Ref 2.
**Gum** is a general term for thick, mucilaginous excretions from various plants. It consists of complex carbohydrates which yield sugars on hydrolysis. The gums either dissolve or swell in water and may be pptd by alcohol. Gums may be divided into 3 classes:

a) *Arabin* type, completely sol in w, such as gum arabic; b) *Bassorin* type, such as gum dragon, sl sol in w and c) *Cerasin* type, such as cherry gum, swelling in w.

Some of the gums have been used in Dynamites to increase their plasticity (Ref 1, p 406), but their principle use in the expl industry is as binding agents in priming and initiating compns. Being carbohydrates, they function to a certain extent as combustible materials.

**Gum Arabic or Acacia Gum** (Gomme, in Fr). A white powder obt'd by drying the gummy exudation from the bark, stems and branches of the Acacia Senegal trees (or other acacia species). It is completely sol in w, forming a glue which is fairly strong. It has been used in some exprs, such as Grentite, and in some priming mixts. It has also been used in some Pyrotechnic compns, as the following colored smokes: K perchlorate 25, antimony sulfide 20, dye (such as rhodamine red, methylene blue or malachite green) 50 and gum arabic 5.

Due to the hygr of gum arabic, it has been replaced in some mixts by linseed oil and, more recently, by Parlon, which is Hercules Powder Co chlorinated rubber, supplied as a white granular powder intended for use in corrosive resistance paints as a film former (Ref 7).

Requirements of the US Armed Forces for gum arabic are covered by Spec JJJ-G-821, and are as follows:

1) Insoluble residue — max 1.0%
2) Total ash — max 4.0
3) Acid-insoluble ash — max 0.5
4) Moisture — max 15.0
5) Tannin-bearing gums — none
6) Starch and dextrin — none
7) Identification: When 0.2ml of 4% Pb subacetate is added to 10ml of 2% aqueous soln of gum arabic, a flocculent or curdy ppt shall form immediately.

8) Solubility. When 35g of the sample is added to 100ml water and allowed to stand, with occasional shaking for 18–24 hours, the resulting liquid shall be free-flowing, uniform in appearance and without any indication of ropiness.

9) Reduction of *Fehling*’s solution. Not more than a trace of CuO shall be formed when the material is tested with Fehling’s solution.

10) Acidity — Inorganic, none; Organic, max 0.40% as acetic acid.

**Gum, Green.** This is not really a gum but finely powdered coconut shell. It is not sol in w (Ref 4, p 4).

**Gum Dragon or Gum Tragacanth.** A gummy exudation from the stems of trees, such as Astragalus gummefer etc, mostly native to Asia Minor. It is sl sol in w and is used as a binding agent in some Priming Compositions in lieu of gum arabic etc (Ref 1, p 406, Ref 2, p 455 and Ref 5, p 1154-R). Requirements of the US Armed Forces are covered by Spec JAN-G-96A, and are as follows:

1) Color — white to light tan (by visual observation)
2) Form — leaf or flake-like (by visual observation)
3) Odor — none
4) Chlorine as chlorides — none
5) Acidity — Inorganic, none; Organic, max 0.40%
6) Foreign gums — none
7) Indian gums — none
8) Ash — max 3.5%

**Gum, Guar** is described here separately as **Guar Gum**.

**Gum Kaori (Copal Resin).** This is not really a gum because it is not sol in w and does not swell in it. It is a fossil resin obt'd from New Zealand. It is yol to yel-brn, insol in w and the usual solvents. It has been used in some pyrotechnic compns (Ref 3, p 466-L & Ref 4, p 4).
Gum Lac or Shellac. It is obtd from a resin secreted by the insect Laccifer laca and deposited on the twigs of various species of trees in India, Siam and Indo-China. The collected material is dried, ground and washed to remove the adherent red dye. Then the material is melted, strained and flaked, similarly as in procedures described in this Vol, p F44-L, under Flaking. This gives orange shellac of commerce. White shellac is obtd by bleaching orange shellac with Na hypochlorite. Both are insol in w, but sol in alc. Their extensive list of uses includes: paints, varnishes, dielectric compons, sealing wax and match heads (Ref 3, 768-L & Ref 5, 1018-L)

Gum-resins (Oleoresins). A group of aromatic exudations of plants which consist of mix of various substances (as essential oils) with the gum. The following are official (ISP): ammoniac, assafetida, gamboge, myrrh and scammony (Ref 3, p 392-L & Ref 5, p 327-R (Oleoresins))

Gum Sandarac or Juniper Gum. The resinous substance which exudes from Callitris quadrivalvis, found in Morocco; vel, brittle, amorph substance; sol in alc, eth, acet, chl & other solvents, insol in w, benz & light petr hydrocarbons. Used as incense, varnishes, lacquers and probably suitable as binder in expl compons (Ref 3, p 755-L (Sandarac) & Ref 5, p 999-L (Sandarac Gum))

Gum-sugar (Arabinose), C₉H₁₄O₅, is a syrupy concd sugar soln in glycerol which does not crystallize. It was used in Germany in some Dynamites when it was required to render them plastic without the addn of a large amount of NG-NC gel. It might be said that gum-sugar saved or "stretched" NG gelatin (Ref 5, p 103-R (Arabinose) [See also under "Extending (Stretching or Lengthening) Gelatin-Dynamites in this Vol, p E496]

Gum-tree (Red gum, Sweet gum). Gum obtd from a tree grown in the swamps of the Mississippi river and from the Kangaroo islands near Australia. It has been used as a binding agent in some pyrotechnic compons, eg in the following "Simulated Booby Trap" illuminating compn: Red gum 13 to 15, dextrin 5.5 to 6.5 & KC10₄ 78-82% (Refs 1, 3 & 4)

Refs: 1) Naoum, NG (1928), p 406 2) Davis (1943), 455 (Gum arabic and Gum tragacanth) 3) Hackh's Dict (1944), 392-L (Gums); 392-L (Gum-resins); 392-R (Gum-tree); 466-L (Kauri Gum) 4) G. W. Weingart, "Pyrotechnics", ChemPugCo, Brooklyn (1947), 4-5 & 194-95 5) CondChemDict (1961), 334-R (Gums); 103 (Arabic Gum); 103 (Arabinoose); 851-R (Parlon); 1154-R (Tragacanth Gum) 6) Kirk & Othmer, Vol 10 (1966), pp 741-54 (Gums, natural) 7) CondChemDict (1971), 75 (Arabic gum), 429 (Gum, natural), 659 (Parlon) 8) US Specification JAN-G-276 (Gum, ester); MIL-G-96A (Gum, Tragacanth) (For use in ammo)

Gum Incendiaries, such as 8% rubber soln in benzene, proved to be (when used in incendiary bombs) about ½ as effective on the wt basis as magnesium bombs. Being a sticky material, gum incendiary proved to be particularly suitable for use in scatter bombs. This material was about 5 times as effective as Thermite or SDO-sodium nitrate incendiaries Ref: L.F. Fieser, OSRD 173(1941)

Gummidynamit. A German rubber-like, elastic mass obtd by dissolving Collod Cotton in NG. Its compn is similar to Sprenggelatine (Blasting Gelatin)

Re: PATR 2510(1958), p Ger 83

GuN. Abbrn for Guanidine Nitrate

GUN. There is great confusion in definition of this term

Greener (Ref 1, p 565) defined it as "a thermodynamic machine by which the potential energy of the explosive is converted into the kinetic energy of the projectile". Although he does not describe in his book any artillery pieces, the meaning of his definition is that
any weapon which uses an explosive for propelling a projectile is a gun. This corresponds to definition given in Glossary of Ordn (Ref 7), in which it is said that gun, in general, is a piece of ordnance consisting essentially of a tube or barrel, for throwing projectiles by force, usually the force of an explosive, but sometimes that of compressed gas, spring, etc. This general term embraces such weapons as are sometimes specifically designated as: gun, howitzer, mortar, cannon, firearm, rifle, shotgun, carbine, pistol and revolver. To these should be added recoilless gun, machine gun, submachine gun, rocket launcher and guided missile launcher. Specifically, a gun can be defined as a long-range artillery piece with a relatively long barrel (usually longer than 30 calibers), with relatively high initial velocity, high pressure, and capable of being fired at a low angle of elevation, say under 20°.

The first of these definitions (general) is contradictory to definition given in TM9-3305-1 (Ref 6), which is described in Ref 8, p C26-R. It defines a gun, as a cannon and then it is said that the term “gun” is also applied to all firearms. More confusion was added by Ohart (Ref 4, p 3) who said: “A cannon is any large weapon too heavy to be carried by hand. Guns, howitzers and mortars (except trench mortars) are types of cannon.”

If definition of gun given in Ref 7 is correct, then the definitions of other weapons should be reworded as:

a) Howitzer is a gun with a length of barrel shorter, chamber pressure & muzzle velocity lower, range shorter and angle of fire (up to 65°) higher than those of guns (Ref 8, p C27-L)
b) Mortar is a gun with a barrel shorter, muzzle velocity lower, angle of fire higher (up to 85°) and range shorter than those of howitzers (Ref 8, p C27-R)
c) Recoilless Rifle is a gun which permits the discharge of projectiles with no rearward movement of barrel or mount (recoil) (Ref 8, p C28-R)

Other definitions given in Ref 8 include trench mortar (p C28-L), rocket launcher (p C28-R) and guided missile launcher (p C29-L).

The following US guns of WWII are listed in Ref 8, p C27-L: field, aircraft, antiaircraft, tank, railway & seacoast and Naval. There were also antitank (A/T) guns.

The following artillery weapons are now used by the US Armed Forces:

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-mm Automatic Gun, M1A2</td>
<td>Antiaircraft</td>
</tr>
<tr>
<td>40-mm Gun Cannons, M1, M1A1, M2, M2A1 &amp; Mk 1 (Navy)</td>
<td>Antiaircraft</td>
</tr>
<tr>
<td>57-mm Recoilless Rifles, M18, M18A1 &amp; T15E16</td>
<td>Direct Fire</td>
</tr>
<tr>
<td>60-mm Mortars, M2 &amp; M19</td>
<td>Ground Fire</td>
</tr>
<tr>
<td>75-mm Gun Cannon, M3</td>
<td>Tank Weapon</td>
</tr>
<tr>
<td>75-mm Gun Cannon, M35</td>
<td>Antiaircraft</td>
</tr>
<tr>
<td>75-mm Pack Howitzer Cannon, M1A1</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>75-mm Recoilless Rifles, M20 &amp; T21E12</td>
<td>Direct Fire</td>
</tr>
<tr>
<td>76-mm Gun Cannons, M32 &amp; M48</td>
<td>Antitank</td>
</tr>
<tr>
<td>81-mm Mortars, M1 &amp; M29</td>
<td>Ground Fire</td>
</tr>
<tr>
<td>90-mm Gun Cannons, M1 &amp; M2</td>
<td>Antiaircraft</td>
</tr>
<tr>
<td>90-mm Gun Cannons, M36, M41 &amp; M54</td>
<td>Antitank</td>
</tr>
<tr>
<td>90-mm Recoilless Rifle, M67</td>
<td>Direct Fire</td>
</tr>
<tr>
<td>105-mm Gun Cannon, M68</td>
<td>Antitank</td>
</tr>
<tr>
<td>105-mm Howitzer Cannons, M2, M2A2, M4, M4A1 &amp; M49</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>105-mm Recoilless Rifles, M27 &amp; M27A1</td>
<td>Antitank</td>
</tr>
<tr>
<td>106-mm Recoilless Rifles, M40A1 &amp; M40A1C</td>
<td>Ground Fire</td>
</tr>
<tr>
<td>4.2-inch Mortar, M30</td>
<td>Antiaircraft</td>
</tr>
<tr>
<td>120-mm Gun Cannons, M1A1, M1A2 &amp; M1A3</td>
<td>Antitank</td>
</tr>
<tr>
<td>120-mm Gun Cannon, M58</td>
<td>Aircraft Gun</td>
</tr>
<tr>
<td>152-mm Gun Cannon, M81</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>155-mm Gun Cannons, M2 &amp; M46</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>155-mm Howitzer Cannons, M1, M1A1, M45 &amp; M126</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>165-mm Gun Cannon, XM135</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>175-mm Gun Cannon, M113</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>8-inch Howitzers, M2 &amp; M2A1</td>
<td>Field Artillery</td>
</tr>
<tr>
<td>280-mm Gun Cannon, M66</td>
<td>Field Artillery</td>
</tr>
</tbody>
</table>
Ohart (Ref 4, p 173) tabulates the calibers of US artillery weapons used by the Army during WWII. The categories listed are mobile, railway & seacoast, tank armament, antiaircraft, and aircraft armament.

*Note:* Accdg to Staff, Ordn 38, 607 (1954), a gun was developed which is capable of firing atomic shells. This gun is a caliber 280-mm weapon and can hurl projectiles with greater accuracy than any other artillery piece. It can move along a highway at 35 miles/hr across country, can be emplaced in mins, and can be fired around the compass. The gun is so delicately balanced that one man can elevate or depress it by hand should the power mechanism fail. This has been a most dramatic advance in a program to build firepower for defense noted the US Army Secretary.

The Germans developed before and during WWII more new types of guns than all other Nations (Austria, Belgium, Czechoslovakia, France, Gt Britain, Italy, Japan, Poland, Russia, Spain, United States of America and Yugoslavia). A practically complete list of their guns and of other weapons (including numerous illustrations), beginning with 2-cm cannons and ending with 80-cm Gustav Geschütz, used at the siege of Sevastopol' is given in PATR 2510 (1958), pp Ger 237 to Ger 262, incl Als.

*Note:* Germany listed calibers of their guns in cm instead of mm.

One of their best known guns was invented during WWI. It was *Paris Gun* (Parisgeschütz oder Ferngeschütz). It existed in several calibers and lengths and was described in Vol 2 of Encycl, p B113-R, under Big Bertha, although the name Big Bertha must be (accdg to W. Ley, Coast Artillery Journal, Jan-Feb 1943, pp 14–15) referred to as 42cm, L/14 Howitzer and not as Paris Gun. Besides the Paris Gun (officially known as Kaiser Wilhelm Geschütz), several other big guns are listed on p B113-R and B114-L of Vol 2.

Although we cannot list all German guns, many of them conventional, it is necessary to list and describe two of them which have interesting construction, although they do not seem to be of practical use.

One of them, known as *Hochdruckpumpe oder V-3* (High-Pressure Pump or Revenge Weapon-3) (V-3 stands for Vergeltungswaffe 3), also known as "HDP Supergun". It is described in PATR 2510 (1958), p Ger 90 with illustration shown below.

The barrel, caliber 150mm, was of unalloyed crucible cast steel made up of many Y-shaped sections, each 12–16 ft long. With such a gun about 450 ft long contg 28 propellant chambers, it was expected to achieve a muzzle vel of 4500 ft/sec and a range of about 130 km (using a proj 8 ft long and weighing 150 lbs).

The gun could lie on the ground, without any carriage, on blocks sloped at a 45° angle. The fin-stabilized arrow proj was inserted in the barrel and the base propellant charge electrically initiated. As the proj passed the separate Y-pieces, addtl propellant charges in...
the side arms were ignited one after another, thus accelerating the vel of the proj as it progressed along the barrel.

Another interesting German gun of WWII was Wind Gun, developed in Stuttgart. It was designed to shoot a mass of air at an airplane in such a way as to bring it down. The energy for projecting the air was supplied by heat produced on burning a mix of oxygen and hydrogen. It was claimed that the air shot from this gun could break a 1-inch board at a range of 200 meters, but at longer ranges it was not effective (See drawing).

Ref: L.E. Simon, "German Research in WWII", Wiley, NY (1947), p 180

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It does not seem that other countries participating in WWII developed any original types of guns. Most of them were either of WWI or prior to WWII. Many of the Belgian, Dutch, French, Czech, Norwegian, Polish, Russian and Yugoslavian (and some British) guns were captured by Germans and used by them. They are listed together with regular German Guns in PATR 2510 (1958), pp Ger 237 to Ger 262. They were marked by letter f for French, as for example: 2cm GebFlak (f); i for Ital: 2cm M35 (i); p for Polish: 3.7cm Pak (p); r for Russian: 7.62cm KK (r); e for English: 8.38cm FK271 (e); b for Belgian: 7.5cm FK (b); j for Yugoslavian: 7.65cm FK (j); h for Dutch (Holland): 7.5cm FK (h); t for Czechoslovakian (Tschekoslovakie): 7.5cm FK17 (t); n for Norwegian: 7.5cm FK01 (n), etc.

For Russian guns of WWII we have good illustrations on seven separate sheets of PATR 2145 (1955). The artillery pieces include items ranging from 25mm Antiaircraft Gun M1940 to 152mm Howitzer 1943 and 160mm Mortar. There are also illustrations of rocket launchers: 82mm, 132mm, M-13 and 300mm M-31. Also included illustrations of Armored Car BA-64; Medium Tank and two Heavy Tanks. Most popular of Russian guns are 76.2mm and they are considered just as good as famous French 75mm guns.

2) Hayes (1938), 59-370
4) Ohart (1946), pp 3, 5 & 173
7) Glossary Ordn (1959), 142-L

Gun Ammunition Components. Historical discussion giving mechanical and chemical details on development of these components is in Ref
Ref: H.S. Rentell, JJuniorInstEngrs 54, 245-57 (1944) & CA 39, 621 (1945)

Gun, Atomic. See Note under Gun and under Nuclear Weapons

Gun-Barrel Corrosion Inhibitor. A mix of mineral oil 0.5, kerosene 0.15, and colloidal graphite 1 kg when applied to small shot, checks the corrosive action of Gunpowder on gun barrels.
Gun Breach is the rear part of the bore, especially the opening that permits the projectile to be inserted in the rear of the bore. It is closed, after insertion of round of ammo, by breechblock. This usually contains the firing pin and in many types of guns it is also used to chamber the round. The mechanism which unlocks and withdraws the breechblock from the breech is known as breechblock operating mechanism. After firing the round the mechanism serves to open the breech for ejection of empty cartridge and for loading a new charge
Ref: GlossaryOrdn (1959), 48-R & 49-L

Gun Carriage is mobile or fixed support for a gun. It sometimes includes elevating and traversing mechanisms. Wheeled carriage was invented ca 1470
Ref: GlossaryOrdn (1959), 148-R

Guncotton. Nitrocellulose of high nitrogen content (13.35 to 13.45%). It is described in Vol 2 of Encycl, under CELLULOSE NITRATE, p C106-R to C108-R

Guncotton Compressed. It was mentioned in Vol 2 of Encycl, p C101-R that E.A. Brown (asst to F. Ahel) discovered that dry compressed NC could be made to detonate violently by MF cap, such as A. Nobel had used to detonate NG. The chge was too sensitive and could not be used for military purposes. This discovery took place ca 1869. Brown also discovered later that compressed Guncotton contg 15–20% water also could be detonated by MF cap, provided there was a small intermediate chge of dry compressed Guncotton (principle of booster). This permitted the use of large blocks of moist compressed Guncotton quite safely
Russians took advantage of this discovery and started to use compressed Guncotton contg 18% water beginning in 1885 as bursting chgs in shells, bombs, mines and torpedoes. They continued using it till after Russo-Japanese War (1904–1905) or even later. This is described in Vol 3 of Encycl, p C491-L. Dr Fedoroff served during WWI on a small Russian destroyer Zavetniy (350 tons, 27 knots), noticed that warheads of Whitehead torpedoes were charged with moist compressed Guncotton
A very strongly compressed Guncotton, prepd in 1890's by S.P. Vukolov, resembled in its appearance elephant's tusk, and for this reason was called Slonit, which means Elephantide. It was used as a propellant (Ref 2, p Rus 21)

Compressed moist Guncotton was not powerful and one of the reasons was its low density of loading (1.0 to 1.1) because there were many air spaces in the block. This was improved after A. Hollings patented a method of prepn giving compressed blocks with density of 1.25. This method and its modification by G. Bell (1903) are described by Worden (Ref 1, p 2168). Another method of block-forming was proposed in 1905 by A.

Muskok (Ref 1, p 2174). In 1907 J. Carter patented a method in which the chges were made in longitudinal halves or sections to fit the projectile by compression in molds, where the pressure was exerted in a direction transverse to the axis of the mold. The sections were then united by means of colloidion soln, to form a single piece. There was no necessity to use lathe-turning (Ref 1, p 2173)

Methods of manuf of wet compressed Guncotton in Austria and Germany are described in Ref 1, pp 2174–76

The use of compressed, moist Guncotton was discontinued at the beginning of this century, being replaced by PA and TNT
**Guncotton Dynamite** is a nongelatinous expl
invented by Trauri & Abel in 1867. It was
prepd by mixing NG 73, Guncotton 25 &
charcoal 2 with 15 parts of w and using it in
the wet state. It required a strong Blasting
Cap for detonation. A similar expl was
Dualim, used in the US. These expls may be
considered as the oldest Dynamites using an
active base

Guncotton Dynamites were brisant expls,
but their density was low and they required
large bore-holes

With the invention of the Gelatin Dynamites by A. Nobel, the manuf of Guncotton Dynamites was discontinued
**Ref:** Naoiim, NG (1928), p 282

**Gun Flash.** Same as Muzzle Flash

**Gun Gases in Combat Aircraft.** (Prevention
of Explosion). Residual gases from functioning
machine guns form expl mixts with air.
Their expln in the gun compartment of combat-type aircraft may cause considerable damage.
The following is a typical percentage compn
of gun gas after elimination of water vapor by
expansion and cooling: CO₂ 14, H₂ 19, CO
52, CH₄ 1 & N 14%. Expts indicate the avg
value of the lower expl limit to be 11.3%
dry gun gas at sea level. The simplest
method of reducing the hazard is to provide ade-
quate ventilating air and to distribute it
properly
**Ref:** J.J. Horan et al, AeronautEngRev 11,
No 3, 37-43 (1952) & CA 46, 7331 (1952)

**Gun and Guided Weapon.** A discussion of
the relative advantages of guns (antitank)
and guided weapons is given in Refs. From
past experience in the last ten years it seems
that the modern arsenal should have both
**Refs:** 1) Lt Col I.S. Weeks, Ordn 55, pp
552-55 (1971) 2) Editor’s Note on p 486, 
Ord May-June (1973)

**Gun Life Factor (GLF)** (British). If the use-
ful life of a gun using Cordite MD (MC)
equal to about 2000 firings for the smaller
field guns is arbitrarily taken as unity (1),
then the number of firings of a gun using
Cordite Mark I would be only one third (0.33).
The values 1, 0.33, etc are called "gun life
factors". The factor for Cordite RDB is
1.8, for Cordite SC 0.97, for Cordite "Cooled
SC" 1.2 and for British Flashless (various
comps) 3.7 to 8.0. Comps of Cordites are
given in Vol 3 of Encycl, p C534. See Vol 3,
pp C532-Lff for compn of Cordites

**Gun Liquid Propellant of Detroit Controls
Corporation** consists of mixts of hydrazine,
hydrazine nitrate & water for achieving hypervelocities with service wt projectiles
**Ref:** Detroit Controls Corp, Monthly Progress
Rept 33, "Liquid Propellant Gun Systems",
May 1956 (RC-198), Redwood City, Calif

**Gun Machine.** See Machine Gun

**Gun Mantlet** is, accdg to definition given by
Col G.B. Jarrett of Aberdeen Proving Ground,
the main basic support for the tank cannon.
It is so designed as nor only to afford the
elevation and depression of the gun but also
it becomes part of the forward armor of the
turret. Attached to this mantlet, is the spe-
cial armor necessary for the gun recoil system

**Gunmetal** (Bronze). An alloy of Cu 90 and
ca Sn 10 parts with 2% Zn, 1% Pb and small
quantities of Ni, Sb, Fe & Al. Formerly used
for casting cannons
**Refs:** 1) Hackh’s Dict (1944), 392-R
2) CondChemDict (1971), 429-R

**Gunnery** is the art or practice of using cannons or machine guns either on the ground or in the air (Ref 6). It comprises the following three subjects: a) exterior ballistics; b) interior
ballistics; and  c) gun construction (Ref 1) (See also under Ammunition and Weapons in Vol 1, pp A383-L to A391-R. See also under Artillery, Vol 1, p A492-L and Ballistics, Vol 2, p B7-L)  

Gunpowder, Black. Brit for Black Powder, which is described in Vol 2 of Encycl, pp B165-L to B175-R

Addl Ref: F.E. Pounder of Chemical Inspectorate (Brit), "Contaminants in Gunpowder", March 1963 (PA Library C100713) (Not used as a source of info)

Gunpowder, Brown. See BkPdr Modification, known as Brown-, Cocoa- or Chocolate Powder described in Vol 2 of Encycl, p B173-L. It is also listed under CANNON PROPELLANT on p C30-L of Vol 2

Gunpowder, Initiation and Thermal Decomposition of. Initiation is due to formation of local hot spots which may be formed by adiabatic compression of air pockets or by friction of grit particles. The necessary hot spot temperature is 130° which suffices to melt the sulfur. The formation of liquid phase is important, and it is suggested that the process starts with the reaction of sulfur with oxyhydrocarbons present. These latter can be extracted by solvents from the charcoal and also provide a liquid phase. A high pressure is necessary for rapid reaction. Development of initial reaction continues until the main reaction, oxidation of carbon by K nitrate, is established. Acceleration of the initial reaction leading up to rapid burning is controlled by the oxyhydrocarbons in the charcoal. High speed camera reveals that the Gunpowder grains burn slowly layerwise. Rapid propagation from grain to grain is probably due to emission of hot spray of molten droplets of K salts


Gunpowder, White. A mixt of 2 parts K chloride, 1 pt K ferrocyanide & 1 pt sugar
Gun Primer is a device for igniting gun propllnt. It usually consists of an ignition element, a BkPdr booster chge, and an extender tube filled with BkPdr. In smaller calibers it may resemble a fuze primer

Gun Proof Tests. Ballistic Tests in guns are described in the following Refs:
2) Anon, US Army Test and Evaluation Command Materiel Test Procedure, TECP 700-700, Aberdeen Proving Ground, Md (Jan 1967); Ordnance Proof Manual Vol 1, "Arms and Ammunition Testing" (Oct 1957) and Interim Pamphlet Nos:
   20-10 Machine Guns (Feb 1966); MTP 3-2-514
   30-10 Artillery Cannon (May 1965); Material Test Procedure MTP 3-2-509
   30-30 Recoilless Weapons (March 1965); MTP 3-2-066
   30-40 Subcaliber Guns (March 1957); MTP 3-2-518

Gun Propellants, Advanced. A principal development goal in the field of aircraft cannon ammunition has been the development of cool-burning gun propllnt. A new series of cool-burning, high impetus, low molecular weight gun propllnt families, largely based on rocket propllnt technology, have been identified after four years of extensive gun-propllnt development at Eglin AFB. The propllnt families contain either cyclic or linear nitramines as crystalline oxidizers in the propllnt matrix. Table shows the principal linear nitramine compsd studied

These systems are thermally and chemically stable and burn with excellent combustion efficiency when fired in a closed impetus bomb. However, they are not yet ready for operational gun application because of the classical nitramine combustion anomaly; this anomaly being that a single n value, in the empirical formula to describe the burning rate of a propellant \( r = a \rho^n \), can no longer be defined over the entire pressure range. The benefits of high energy/low flame temp formulations, elimination of thermal barrel erosion, use of aluminum cartridge cases, and the realization of hypervelocity aircraft cannon cannot be obtnd until the nitramine combust anomaly is obviated
Ref: O.K. Heiney, NatlDef (formerly Ordn) 58, 152-57, Sept-Oct 1973 (9 refs)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Compound</th>
<th>Formula</th>
<th>Heat of Formation ( \Delta H_F ), kcal/mole</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAGED</td>
<td>Triamino guanidinium ethylene dinitramine</td>
<td>( C_4H_2O_4N_{16} )</td>
<td>-60</td>
</tr>
<tr>
<td>DMDTH</td>
<td>Dimethoxy dinitrazahexane</td>
<td>( C_4H_{14}O_6N_4 )</td>
<td>-94</td>
</tr>
<tr>
<td>DMED</td>
<td>Dimethylethylene dinitramine</td>
<td>( C_4H_{10}O_4N_4 )</td>
<td>-35.8</td>
</tr>
<tr>
<td>DHED</td>
<td>Dihydrizinium ethylene dinitramine</td>
<td>( C_2H_{14}O_4N_8 )</td>
<td>-40</td>
</tr>
</tbody>
</table>
Guns Using Liquid Propellants are briefly described by A.M. Goodall in ARDE (Armanent Research and Development Establishment) Memorandum (P) 3156, Fort Halstead, Kent (Gt Britain) and previous British Reports which are listed on p 16 of the above Memorandum.

Gup or GuPicr. Abbrevs for Guanidinium Picrochlorate.

Gurney Constant and Gurney Formulas. Gurney constant is a factor for use in Gurney formulas. It is constant for each explosive, but varies with different expl. Gurney formulas is a series of formulas, each of them corresponding to a particular geometry of the container, which enables quite accurate prediction of the initial fragment velocity. The velocity is dependent on the geometry, the explosive used and the ratio of the expl charge and metal weight (Ref 1).

The Gurney formula for cylinders is:

\[ V_o = \frac{\sqrt{2E}}{\sqrt{1 + 0.5w_c/w_m}} \text{ ft/sec, while for spheres the formula is the same except that} \]

0.6 is used instead of 0.5.

In these formulas:

\[ V_o = \text{initial fragment velocity, ft/sec} \]
\[ \sqrt{2E} = \text{Gurney constant, ft/sec} \]
\[ w_c = \text{charge weight, lb} \]
\[ w_m = \text{wt of fragmenting metal, lb} \]

The empirical constant \( \sqrt{2E} \) is detd for a particular range of expl to metal ratios. It is expressed as the quantity of energy per unit mass of expl which is available as kinetic energy of fragments. In general, this energy is somewhat more than half of the energy of detonation. Rather than reducing the quantities to theoretical terms, the Gurney constants are given as velocities. Following are Gurney constants, \( \sqrt{2E} \), expressed in ft/sec for three military expls: 8800 for Comp B, 8300 for Pentolite and 7600 for TNT.

The lethality of a fragment is a function of its velocity, weight, and presented area (Ref 2).

Refs: 1) Glossary Ordn (1959), 143-R & 144-L

Gustavus Adolphus, called in French "Gustave II Adolphe le Grand" (1594–1632), King of Sweden from 1611 to 1632, who introduced many innovations in armament, among them the paper cartridge. He was one of the principal participants of Thirty Year War (1618–1648) and conquered a big portion of the Baltic coast which belonged to Russia and Germany. His victories made Sweden one of the biggest countries of Europe. He was killed at the battle of Lützen leading a cavalry attack.


Gustavus Adolphus' Cartridge is described in Vol 4 of Encycl, p 754-55 with Fig 18.

Guttapercha (Gummi plasticum or Isonandra gutta), (C10H16)n. A group of hydrocarbons (such as fluval, alban) with volatile oil. It consists of purified and coagulated milky exudates of various trees of Palagium species, native to S. America & Asia, colorless rubber-like masses, sticks or sheets, sometimes yellowish with red streaks; insol in w; partly sol in carbondisulfide, chlf, turpentine and warm benz; softens ca 65 ° (Ref 1), melts ca 100 ° (Ref 2). Used for insulating wires, waterproofing and can be used as a binder in expl compns.

Refs: 1) Hackb's Dict (1944), 392-R
2) CondChemDict (1962), 555-R
3) CondChemDict (1971), 767-R (See Note under rubber, natural)

Gutter. A portion of an inner liner of a jet engine which is grooved for better operation. Ref: Glossary Ordn (1959), 144-L.
Guttmann, Oscar (1855—1910). German scientist, specializing in explosives. Inventor of one of the stability tests for explosives. Author of numerous publications and books on explosives which were translated into English and other languages. He was killed in an automobile accident in Brussels.


Guttmann's Test. This test for determining the stability of smokeless propellants is not applicable to those containing NG. In Jannopoulos modification, the finely ground propellant is kept before the test at 35—38°C for 4 days to eliminate water and volatiles. The test is conducted in the manner of Abel's Test (See Vol 1 of Encycl, p A2-L, except that as indicator is a solution of DPhA in sulfuric acid & glycerol). The end point is difficult to observe.

Refs: 1) Reilly (1938), 78 2) Kast-Metz (1944), 232 & 309

Gutzeit, Heinrich W. (1845—1888). A German analytical chemist who invented, among other tests, the test for arsenic. The test is performed by adding Zn and dil sulfuric acid to the substance in a test tube, placing on top of it a piece of filter moistened with HgCl₂ solution and observing the formation of yel spot on paper, which turns black on standing

Ref: Hack's Dict (1944), 392-R

Guyton de Morveau, Louis-Bernard (1737—1816). A French lawyer who made chemistry a hobby. He introduced (before Lavoisier), the first chemical nomenclature, promoted the antiphlogiston theory and translated into French many books. He liquefied ammonia.


Gymnastic. Process of artificially exercising a recoil mechanism by mechanical means in order to prevent undue deterioration in storage. Machine for mechanical exercising is called gymnasticator. See also "Exercizer, Recoil Mechanism", in this Vol, p E349-L and in GlossaryOrd (1959), 144-L

Gypsum (Calcium Sulfate Dihydrate, Alabaster), CaSO₄·2H₂O; mw 172.17, sp. gr 2.31—2.33, white substance, mp loses 3/2H₂O by 128°C and rest by 167°C, hardness 1.5 to 2. Occurs naturally in the USA, Canada, England, France, Sicily, Switzerland etc.; sl sol in w; sol in acids, glycerin and aqueous Na₂S₂O₆ and ammonium salts.

Since it contains water of crystallization, and because it is cheap and abundant, it was proposed as a temp reducing (cooling) agent in permissible explosives (See Hydrated Explosives). It was also previously used as a source of sulfur and for the prep of sulfuric acid. Many other uses are listed in Refs 3 & 5


Gyro. Short for gyroscope or gyroscopic

Gyroscope. A device which utilizes the properties of a spinning mass to remain fixed in space. It can be used in a flight instrument which holds the position and indicates deviation from the desired heading. Also used in an autopilot or bombsight mechanism that provides directional stability. In a mechanism called "gyrostabilizer", the vertical motion of a tank gun is stabilized regardless of the pitched motion of moving tank.

Gyroscopic Action (Kreiseleffekt, in Ger). Concerning the possibility of explaining the drift of an elongated shell in rotation by gyroscopic action, a calculation was undertaken in 1839 by S.D. Poisson. But G. Magnus was the first in 1852 to show the main phenomena, by experiments on models in a lab (Refs 1 & 2)


Gyroscopic Movement of Projectiles. The English theory of gyroscopic projectile flight was modified to take into account the variation of air resistance and the moment of this force with the "yaw" or obliqueness of a projectile in flight (Refs 1 & 2)