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AMC PAMPHLET

AMCP 706-177

# ENGINEERING DESIGN HANDBOOK

## EXPLOSIVES SERIES PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

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PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts helpful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 706-177, Properties of Explosives of Military Interest, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are listed herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were first compiled for publication at Picatinny Arsenal, Dover, New Jersey, by W. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheftield, also of Picatinny Arsenal, for the Engineering Handbook Office of Duke University, prime contractor to the Army Materiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to other DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer  
Letterkenny Army Depot, ATTN: AMXLE-ATD  
Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer proper justification to the address listed in par. a.

c. Government agencies other than DOD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

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U. S. Army Materiel Command  
ATTN: AMCAM-ABS  
Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

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U. S. Army Materiel Command  
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Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence  
Foreign Liaison Office  
Department of the Army  
Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a valid justification.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

## ABBREVIATIONS AND SYMBOLS

~	approximately. This symbol is used before numbers.
AC	Advisory Council on Scientific Research and Development, Great Britain.
ACS	American Chemical Society.
AISI	American Iron and Steel Institute.
Ann	Liebig's Annalen der Chemie.
Ann chim phys	Annales de chimie et de physique.
AP	armor-piercing.
APG	Aberdares Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-HEC	British Intelligence Overseas Service or Objective Subcommittee, Group 2, Halstead Exploiting Center.
BM	Bureau of Mines, United States Department of Interior.
Bull Soc chim	Bulletin de la societe chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
dec	decomposes.
ΔH	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
E	modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in lb/inch <sup>2</sup> .
E'	same as E, but expressed in dynes/cm <sup>2</sup> .
Gazz chim ital	Gazzetta Chimica Italiana.
GP	general purpose.
HE	high explosive.
HEAT	high explosive antitank.
Ind Eng Chem	Industrial & Engineering Chemistry.
J Am Chem Soc	Journal of the American Chemical Society
J Chem Ind	The Journal of the Society of Chemical Industry (London).
J Chem Soc	Journal of the Chemical Society (London).
J Frank Inst	Journal of the Franklin Institute.
J Iod Explosives Soc	Journal of the Industrial Explosives Society (Japan).
J prakt Chem	Journal für praktische Chemie.
LA	lead azide
Land-Bornst	Lardolt-Bornstein Physikalisch-Chemische Tabellen, 5th Edition (Berlin).
M	molar.
M	Monatshefte für Chemie (Wein).
Mém poudr	Mémoires des poudres et salpêtres (Paris).
mg	milligram.

## ABBREVIATIONS AND SYMBOLS (cont'd)

min	minimum.
ml	milliliter.
m/s	meters per second.
MW	molecular weight.
NAVORD	Bureau of Ordnance (U. S. Navy)
NC	nitrocellulose.
$n_D^{20}$	index of refraction, with D band of sodium as light source, at twenty degrees centigrade.
NDRC	National Defense Research Committee.
NFOC	National Fireworks Ordnance Corporation.
NG	nitroglycerin.
MOL	U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.
MOTS	U. S. Naval Ordnance Test Station, China Lake, Calif.
NRC	National Research Council.
OB	oxygen balance.
OCH	Ordnance Committee Minutes.
OSRD	Office of Scientific Research and Development.
PA	Picatinny Arsenal.
PATR	Picatinny Arsenal Technical Report.
Phil Trans	Philosophical Transactions of the Royal Society of London.
Pogg Ann	Poggendorf's Annalen der Physik.
Proc Roy Soc	Proceedings of the Royal Society of London.
Rec trav chim	Recueil des travaux chimiques des Pays-Bas.
RH	relative humidity.
RI	Report of Investigation.
SAE	Society of Automotive Engineers.
SAP	semi-armor-piercing.
soi	solution.
Spec	Specifications.
std dev	standard deviation.
TM	Technical Manual, Department of the Army.
TM/TO	joint publication, as a TM and as a Department of the Air Force Technical Order.
Trans Farad Soc	Transactions of the Faraday Society
vac stab	vacuum stability.
Z angew Chem	Zeitschrift für angewandte Chemie.
Z anorg Chem	Zeitschrift für anorganische und allgemeine Chemie.
Z ges Schieß- Sprengstoffw	Zeitschrift für das gesamte Schieß und Sprengstoff- wesen (München).
z/sec	atoms of oxygen per second.

## PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

### INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Unisera Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METHODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

- (1) Name of the explosive in each instance.
- (2) "Composition."
- (3) "Impact Sensitivity, 2 Kg Wt."
  - (a) Impact sensitivity test for solids. (a)\*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

\*Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

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height at which at least one of 10 trials results in explosion. For the BM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63  $\pm$  2) steel surfaces; in the latter case, it is placed in the depression of a small steel die-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the BM apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the die-cup cavity), and (3) involves a frictional component against the inclined sides.

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated herein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PI Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wet the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

1. The weight of explosive tested is 0.007-gm.

2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter, is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.

(4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and unaffected.

(5) "Rifle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is loaded in the same manner as it is loaded for actual use: that is, cast, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/16-inch wall) closed on each end by a cap. The loaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax plug. The loaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

## (6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is immersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action.

## (7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75°C. The sample after this exposure is observed for signs of decomposition or volatility.

## (8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100°C. It is also noted whether exposure at 100°C for 100 hours results in explosion.

## (9) "Flammability Index." (h)

The measure of the likelihood that bare charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

## (10) "Hygroscopicity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

## (11) "Volatility."

A 10-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

## (12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

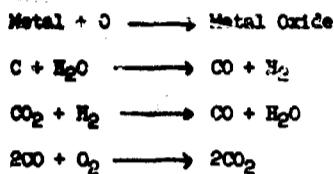
$$\text{MW of mixture} = \frac{100}{\frac{a}{\text{MW}_1} + \frac{b}{\text{MW}_2} + \frac{c}{\text{MW}_3} + \frac{n}{\text{MW}_n}}$$

where a, b, c and n are the weight percents of the components, and MW<sub>1</sub>, MW<sub>2</sub>, MW<sub>3</sub> and MW<sub>n</sub> their corresponding molecular weights.

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(13) "Oxygen Balance."

The oxygen balance (OB) is calculated from the empirical formula of a compound in percentage of oxygen required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following order:



Procedure for calculating oxygen balance is to determine the number of grammes of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

$$\text{the oxygen balance: } 1600 (2I + \frac{Y}{2} - Z)$$

+ molecular weight of compound = oxygen balance to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , where I = atoms of carbon, Y = atoms of hydrogen, Z = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The carbon/hydrogen (C/H) ratio is calculated as follows:

$$\frac{\text{Number of C atoms } (4C + 4H)}{\text{Number of H atoms } (100)} = \text{C/H ratio}$$

- (14) "Density."
- (15) "Melting Point."
- (16) "Freezing Point."
- (17) "Boiling Point."
- (18) "Refractive Index."
- (19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried, is heated for 40 hours, in vacuo at the desired temperature.

(20) "200 Gram Bomb Sand Test."

- (a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 cap, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample crushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquids. (b)

The sand test for liquids is made in accordance with the procedure given for solids except that the following procedure for loading the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead azide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to avoid squeezing the charge. Transfer a weighed portion of 0.400 gm of the test explosive to an aluminum cap, taking precautions when the explosive is liquid to insert the sample in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid explosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap: height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead azide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in grams, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample under test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

$$\text{TNT value} = \frac{10}{\text{sample weight}} \times 100.$$

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-nosed mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TNT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety

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of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boosterized by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

(b) Method B - A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates as backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

$$\text{Plate dent test value, or relative brisance} = \frac{\text{Sample Dent Depth}}{\text{Dent Depth for TNT at } 1.61 \text{ gm/cc}} \times 100.$$

(25) "Detonation Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Brugeton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

- (3) "Specific Heat."
- (4) "Burning Rate."
- (5) "Thermal Conductivity."
- (6) "Coefficient of Expansion."
- (7) "Hardness, Mohs' Scale."
- (8) "Young's Modulus."
- (9) "Compressive Strength."
- (10) "Vapor Pressure."
- (11) "Decomposition Equation."
- (12) "Armor Plate Impact Test." (J)
  - (a) 60-mm Mortar Projectile.

A modified 60-mm, M49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (bazooka), 5 gm of 4F black powder, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

- (b) 500-lb General Purpose Bombs.
- (13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing either inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

- (1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M20 Booster pellets, and those used with 3-inch HE, M42A1, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50  $\pm$  0.10 gm, and 0.480 to 0.485 inch.

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The projectile assembled with fuze, actuated by a Blasting Cap, Special, Type II (Spec 49-20) placed directly on a lead of comparable diameter, and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside dimensions. The box with projectile is placed on about 4 feet of sand in a steel fragmentation tub, the detonator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fragment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourmaline gages, and the usual necessary specialized electrical circuits, shielded co-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TNT = 100." (k, m)

Unconfined charges 2 inches in diameter and 6 inches long, boosted by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. M9Al steel cones are used. Results are averages of 4 trials.

(5) "Color."

(6) "Principal Uses."

(7) "Method of Loading."

(8) "Loading Density."

(9) "Storage."

Ammunition and bulk explosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

(a) Method: Wet or dry.

(b) Hazard Class (Quantity-Distance).

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Ammunition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Material Command Regulation, AMCR 385-100, AMC Safety Manual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TQ 11A-1-3).

(c) Compatibility Group.

Explosives and ammunition are grouped for compatibility with respect to the following factors:

1. Effects of explosion of the item.
2. Rate of deterioration.
3. Sensitivity to initiation.
4. Type of packing.
5. Effects of fire involving the item.
6. Quantity of explosive per unit.

(d) Endudation.

(e) Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

- (1) Solubility.
- (2) Methods of manufacture.
- (3) Historical information.
- (4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the Naval Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

(5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electrometric pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube (~ 7 mm ID x 18 mm long) which fits over a metal peg. The volume of the space around the charge at zero gap is ~ 0.15 cc; at a gap of 0.6 mm, it is ~ 0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condenser is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detonation with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead azide, mercury fulminate and nitroglycerin.

(8) Other information.

(9) References.

6. REFERENCES CITED IN INTRODUCTION.<sup>1</sup>

- a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PATR No. 1401, 18 March 1944, Revised 28 February 1950.
- b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.
- c. J. H. McIvor, Friction Pendulum, PA Testing Manual 7-1, 8 May 1950.
- d. Departments of the Army and the Air Force Joint Technical Manual and Technical Order, TM 9-1910/TC 11A-1-34, Military Explosives, April 1955.
- e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.
- f. Ph. Macum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.
- h. NDRC Interim Report, Preparation and Testing of Explosives, Nos. PT-19 and PT-20, February-April 1944.
- i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.
- j. Report AC-2983/Org Expl 179.

<sup>1</sup>For information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

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k. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NIRC Contract W-572-ORD-5723.

l. J. H. McIvor, Fragmentation Test Procedures, PA Testing Manual 5-1, 24 August 1950.

m. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NIRC Contract W-572-ORD-5723.

n. F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of Interior, Bureau of Mines, R. I. 3552, 1946.

o. D. D. Sager, Study of Acid Adsorption and Hydrolysis of Cellulose Nitrate and Cellulose Sulphate, PATR No. 174, 12 January 1932.

p. L. C. Smith and E. H. Ryter, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, ORD Report No. 5746, 27 December 1945.

q. C. S. Sandler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Modulus of Elasticity and Associated Loss Factor of Rubber and Plastics, NAVORD Report No. 1584, 1 September 1950.

r. W. S. Cramer, Bulk Compressibility Data on Several Explosives, NAVORD Report No. 4380, 15 September 1956.

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Amatol, 80/20

<b>Composition:</b> %		<b>Molecular Weight:</b>	92
Ammonium Nitrate TNT	80 20	Oxygen Balance: CO <sub>2</sub> %	+1
		CO %	+11
		<b>Density:</b> gm/cc	Cast 1.46
		<b>Melting Point:</b> °C	
		<b>Frosting Point:</b> °C	
		<b>Boiling Point:</b> °C	
		<b>Refractive Index:</b> n <sub>D</sub> n <sub>D</sub> n <sub>D</sub>	
<b>C/H Ratio</b>			
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	90	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Sample Wt 20 mg		90°C	
Picatinny Arsenal Apparatus, in.	15	100°C	0.45
Sample Wt, mg	17	120°C	0.95
		135°C	
		150°C	6.8
<b>Friction Pendulum Test:</b>		<b>200 Gram Bomb Sand Test:</b>	
Steel Shoe	Unaffected	Sand, gm	35.5
Fiber Shoe	Unaffected		
<b>Rifle Bullet Impact Test: 5 Trials</b>			
Explosions	% 0	<b>Sensitivity to Initiators:</b>	
Partials	0	Minimum Detonating Charge, gm	
Burned	0	Mercury Fulminates	
Unaffected	100	Lod Azide	0.20
		Tetryl	0.07
<b>Explosion Temperature:</b> °C		<b>Ballistic Mortar, % TNT:</b> (a)	130
Seconds, 0.1 (no cap used)		<b>Trend Test, % TNT:</b> (b)	123
1			
5 Decomposes 280			
10			
15			
20			
<b>75°C International Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss in 48 Hrs	0.06	Method	
		Condition	
<b>100°C Heat Test:</b>		Confined	
% Loss, 1st 48 Hrs	0.03	Density, gm/cc	
% Loss, 2nd 48 Hrs	0.05	Brisance, % TNT	
Explosion in 100 Hrs	None		
<b>Flammability Index:</b>			
<b>Hygroscopicity: %</b> 30°C, 50% RH, 2 days	61	<b>Detonation Rate:</b>	
<b>Velocity:</b>	N11	Confinement	None None
		Condition	Cast Cast
		Charge Diameter, in.	1.0 1.0
		Density, gm/cc	1.46 1.50
		Rate, meters/second	4500 5100

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
80 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			
For TNT			
For Subject HE			
<b>3 inch HE, M23A1 Projectile, Lot KC-5:</b>		<b>Color:</b>	
Density, gm/cc		Buff-yellow	
Charge Wt, lb		<b>Principal Uses:</b>	
<b>Total No. of Fragments:</b>		Bombs, HE projectiles	
For TNT		<b>Method of Loading:</b>	
For Subject HE		Cast	
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
(r)		1.46	
At 9 ft	1900		
At 25½ ft	1750		
Density, gm/cc			
<b>Blow (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	
Peak Pressure		Dry	
Impulse			
Energy			
Air, Confined:		<b>Hazard Class (Quantity-Distance):</b>	
Impulse		Class 9	
Under Water:		<b>Compatibility Group:</b>	
Peak Pressure		Group I	
Impulse			
Energy		<b>Exudation:</b>	
Underground:		Does not exude at 65°C	
Peak Pressure			
Impulse			
Energy			
<b>Booster Sensitivity Test:</b>		<b>(a)</b>	
Condition		Pressed	
Tetryl, gm		100	
Wax, in. for 50% Detonation		0.83	
Density, gm/cc		1.65	
<b>Heat of:</b>		<b>(d, e)</b>	
Combustion, cal/gm		1002*	
Explosion, cal/gm		490*	
Gas Volume, cc/gm		930*	

\*Calculated from composition of mixture.

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Amatol, 60/40

<b>Composition:</b> %		<b>Molecular Weight:</b>	101
Ammonium Nitrate	50	Oxygen Balance:	
TNT	40	CO <sub>2</sub> %	-18
		CO %	+ 2
<b>C/H Ratio</b>		<b>Density:</b> gm/cc	Cast 1.60
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Melting Point:</b> °C	
Bureau of Mines Apparatus, cm	95	<b>Freezing Point:</b> °C	
Sample Wt 20 mg		<b>Boiling Point:</b> °C	
Picatinny Arsenal Apparatus, in.	16	<b>Refractive Index,</b> n <sub>D</sub> <sup>20</sup>	
Sample Wt, mg	17	n <sub>D</sub> <sup>20</sup>	
		n <sub>D</sub> <sup>25</sup>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
<b>Rifle Bullet Impact Test:</b>	Trials	100°C	
Explosions	%	120°C	
Partials		135°C	
Burned		150°C	
Unaffected		<b>200 Gram Bomb Sand Test:</b>	
<b>Explosion Temperature:</b>	°C	Sand, gm	41.5
Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b>	
1		Minimum Detonating Charge, gm	
5	Decomposes 270	Mercury Fulminate	
10		Lead Azide	0.20
15		Tetryl	0.06
20		<b>Ballistic Mortar, % TNT:</b> (e)	128
<b>75°C International Heat Test:</b>		<b>Trexal Test, % TNT:</b>	
% Loss in 48 Hrs		<b>Plate Dent Test:</b>	
<b>100°C Heat Test:</b>		Method	
% Loss, 1st 48 Hrs		Condition	
% Loss, 2nd 48 Hrs		Confined	
Explosion in 100 Hrs		Density, gm/cc	
<b>Flammability Index:</b>		Brisance, % TNT	
<b>Hygroscopicity:</b> %		<b>Detonation Rate:</b>	
<b>Volatility:</b>	N11	Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.50
		Rate, meters/second	5760

Anatol, 60/40

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Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	1.49	Hole Volume	
Charge Wt, lb	1.971	Hole Depth	
Total No. of Fragments:		Color:	
For TNT	703	Buff-yellow	
For Subject HE	583	Principal Uses:	
3 inch HE, M42A1 Projectile, Lot KC-5:		Bombs, HE projectiles	
Density, gm/cc	1.57		
Charge Wt, lb	0.827		
Total No. of Fragments:		Method of Loading:	
For TNT	514	Cast	
For Subject HE	408		
Fragment Velocity: ft/sec		Loading Density: gm/cc	
At 9 ft		160	
At 25½ ft			
Density, gm/cc		Storage:	
Blow (Relative to TNT):		Method	
Air:		Dry	
Peak Pressure	95	Hazard Class (Quantity-Distance)	
Impulse	85	Class 9	
Energy	84	Compatibility Group	
Air, Confined:		Group I	
Impulse		Exudation	
Under Water:		Does not exude at 65°C	
Peak Pressure			
Impulse			
Energy			
Underground:		Heat of: (d, e)	
Peak Pressure		Combustion, cal/gm	1658*
Impulse		Explosion, cal/gm	633*
Energy		Gas Volume, cc/gm	960*
*Calculated from composition of mixture.			

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Amitol, 50/50

<p><b>Composition:</b> %</p> <p>Ammunition Rupture TNT</p> <p>C/H Ratio</p> <p><b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, c.v. 95 Sample Wt 20 mg</p> <p>Picatinny Arsenal Apparatus, In. 16 Sample Wt, mg 17</p> <p><b>Pellet Penetration Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected</p> <p><b>Rifle Bullet Impact Test:</b> Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100</p> <p><b>Explosion Temperature:</b> °C Seconds, 0.1 (no CCP used) 1 5 Decomposes 265 10 15 20</p> <p><b>75°C International Heat Test:</b> % Loss in 48 Hrs</p> <p><b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs</p> <p><b>Flammability Index:</b></p> <p><b>Hygrosopicity:</b> % Nil</p> <p><b>Velocity:</b></p>	<p><b>Molecular Weight:</b> 118</p> <p><b>Oxygen Balance:</b> CO, % -27 CO % -3</p> <p><b>Density:</b> gm/cc Cast 1.55</p> <p><b>Melting Point:</b> °C</p> <p><b>Frosting Point:</b> °C</p> <p><b>Boiling Point:</b> °C</p> <p><b>Refractive Index:</b> No No No</p> <p><b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.2 120°C 1.0 135°C 150°C</p> <p><b>200 Gram Bench Sand Test:</b> Sand, gm 42.5</p> <p><b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.05</p> <p><b>Ballistic Mortar, % TNT:</b> (a) 124</p> <p><b>Trend Test, % TNT:</b></p> <p><b>Plate Dent Test:</b> Method B Condition Cast Confined No Density, gm/cc 1.55 Briance, % TNT 52</p> <p><b>Detonation Rate:</b> Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.55 1.55 Rate, meters/second 6430 6230</p>
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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm KE, M71 Projectile, Lot WC-91:		Gloss Cores	Steel Cores (s)
Density, gm/cc	1.55	Hole Volume	53
Charge Wt, lb	2.053	Hole Depth	69
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Buff-yellow	
For Subject HE	630		
<b>3 inch HE, MASA1 Projectile, Lot KC-3:</b>		<b>Principal Uses:</b>	
Density, gm/cc	1.54	Bombs, HE projectiles	
Charge Wt, lb	0.819		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT	514	Cast	
For Subject HE	385		
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		1.59	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		<b>Method:</b>	
Peak Pressure	97	Dry	
Impulse	87		
Energy			
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance):</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group:</b>	
Peak Pressure		Group I	
Impulse			
Energy	93		
<b>Underground:</b>		<b>Exudation:</b>	
Peak Pressure	104	Does not exude at 65°C	
Impulse	104		
Energy	104		
<b>Booster Sensitivity Test:</b>		<b>(a)</b>	
Condition		Cast	
Tetryl, gm		100	
Wax, in. for 50% Detonation		0.60	
Density, gm/cc		1.55	
<b>Heat of:</b>		<b>(d. e.)</b>	
Combustion, cal/gm		1990	
Explosion, cal/gm		703*	
Gas Volume, cc/gm		855*	
*Calculated from composition of mixture.			
<b>Specific Heat: cal/gm/°C</b>		<b>(i)</b>	
Temp, 20° to 80°C		0.383	
<b>Bomb Drop Test:</b>			
T7, 2000-lb Semi-Armor-Piercing			
Bomb vs Concrete:			
Max Safe Drop, ft		4000-5000	

Compatibility with Metals:

Dry - Metals unaffected are zinc, iron, tin, brass, brass tin plated, brass NRC coated, brass shellac coated, nickel aluminum, steel, steel plated with nickel, zinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of ammonium nitrate is required if the maximum density of the cast amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Continuous mixing to insure uniformity and load by pouring into shell or bombs.

Origin:

Developed by the British during World War I in order to conserve TNT.

References:<sup>2</sup>

(a) L. C. Smith and E. H. Ryster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report 5746, 27 December 1945.

(b) Report AC-17/Phys Ex 1.

(c) D. P. McLougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(d) Committee of Div 2 and 8, NDRC, Report on HEX and Tritonal, OSRD Report No. 5406, 31 July 1945.

(e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(f) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.

(g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

0	1	2	3	4	5	6	7	8	9
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	754	695	666	1757	838	929
950	1051	1352	1323	874	715	986	1827	1098	1129
1300	1311	1372	1493	1344	735	1376	2167	1148	1219
1530	1451	1552	1763		1145	1446		1388	1369
	1651				1225	1636		1568	1559
					1345	1796		1838	
					1455				
					1885				

(i) TM 9-1910/TG 11A-1-34, Military Explosives, April 1955.

<sup>2</sup>See footnote 1, page 10.

<b>Composition:</b> %	<b>Molecular Weight:</b> <b>102</b>
Ammonium Nitrate 22	Oxygen Balance: CO <sub>2</sub> % CO %
TNT 67	Density: gm/cc <b>1.65</b>
Alumina 11	Melting Point: °C
<b>C/H Ratio</b>	<b>Frosting Point: °C</b>
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg 91	<b>Boiling Point: °C</b>
Picatinny Arsenal Apparatus, in. Sample Wt, mg 11 39	<b>Refractive Index, no</b> no 39
<b>Fritilla Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C 4.4.
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>300 Gram Bomb Sand Test:</b> Sand, gm <b>17.8</b>
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.20 Lead Azide Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b> (a) <b>122</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	<b>Tread Test, % TNT:</b> <b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Flammability Index:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Hygroscopicity:</b> %	
<b>Volatility:</b>	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			<b>Color:</b>
For TNT			
For Subject HE			
<b>8 inch HE, M42A1 Projectile, Lot KC-8:</b>			<b>Principal Use:</b> Projectile filler
Density, gm/cc	1.65		
Charge Wt, lb			
<b>Total No. of Fragments:</b>			<b>Method of Loading:</b> Cast
For TNT	655		
For Subject HE	550		
<b>Fragment Velocity: ft/sec</b>			<b>Loading Density:</b> gm/cc 1.65
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>			<b>Storage:</b>
Air:			Method Dry
Peak Pressure			Hazard Class (Quantity-Distance) Class 9
Impulse			Compatibility Group
Energy			Exudation
Air, Confined:			
Impulse			
Under Water:			<b>Origin:</b>
Peak Pressure			Castable mixture developed in United States
Impulse			during World War I.
Energy			
Underground:			<b>References:</b>
Peak Pressure			(a) W. R. Tomlinson, Jr., <u>Physical and Explosive Properties of Military Explosives</u> , PATR No. 1372, 29 November 1943.
Impulse			
Energy			(b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.
<b>Preparation:</b>			
Procedure same as described under Amatols, except aluminum is added to the ammonium nitrate-TNT molten mixture under agitation until uniformity in composition is obtained. Loading is accomplished by pouring into the appropriate projectile.			

Ammonium Nitrate

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<p><b>Composition:</b> %</p> <table style="margin-left: 20px;"> <tr><td>N</td><td>35</td></tr> <tr><td>H</td><td>5</td></tr> <tr><td>O</td><td>60</td></tr> </table> <p><b>C/H Ratio</b></p> <p><b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm      100+ Sample Wt 20 mg</p> <p>Picatinny Arsenal Apparatus, in. Sample Wt, mg      31 17</p> <p><b>FriCTION PENDULUM TEST:</b> Steel Shoe      Unaffected Fiber Shoe      Unaffected</p> <p><b>8MM Bullet Impact Test:</b> Trials Explosions      % Partials      0 Burned      0 Unaffected      100</p> <p><b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Ignites      465 10 15 20</p> <p><b>75°C Intermittent Heat Test: (a)</b> % Loss in 48 Hrs      0.0</p> <p><b>100°C Heat Test:</b> % Loss, 1st 48 Hrs      0.74 % Loss, 2nd 48 Hrs      0.13 Explosion in 100 Hrs      None</p> <p><b>Flammability Index:</b></p> <p><b>Hygrosopicity:</b> % 30°C, 90% RH      Extreme</p> <p><b>Volatility:</b> Decomposes at 210°C</p>	N	35	H	5	O	60	<p><b>Molecular Weight:</b> (<math>\text{NH}_4\text{NO}_3</math>)      80</p> <p><b>Oxygen Balance:</b> CO<sub>2</sub> %      +20 CO %      +80</p> <p><b>Density:</b> gm/cc      Crystal      1.73</p> <p><b>Melting Point:</b> °C      170</p> <p><b>Freezing Point:</b> °C</p> <p><b>Boiling Point:</b> °C</p> <p><b>Refractive Index:</b> n<sub>D</sub> n<sub>D<sup>20</sup></sub> n<sub>D<sup>25</sup></sub></p> <p><b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C      0.3 120°C      0.3 135°C 150°C      0.3</p> <p><b>200 Gram Bomb Sand Test:</b> Sand, gm      Nil</p> <p><b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate Lead Azide      0.20 Tetryl      0.25</p> <p><b>Ballistic Mortar, % TNT: (a)</b>      56</p> <p><b>Trend Test, % TNT:</b></p> <p><b>Plate Dot Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT</p> <p><b>Detonation Rate:</b> (b) <b>Confinement</b>      None      Strong <b>Condition</b>      Solid      Liquid Charge Diameter, in.      1.25      4.5 Density, gm/cc      0.9      1.4 Rate, meters/second      1000      2500</p>
N	35						
H	5						
O	60						

<b>Burner Sensitivity Test:</b> Condition Tetryl, gm. Max, in. for 50% Detonation Max, gm Density, gm/cc				<b>Decomposition Equations:</b> (r) (b) Oxygen, atoms/sec $10^{13.8}$ $10^{12.3}$ (Z/sec) Heat, kilocalories/mole 40.5 38.3 (AH, kcal/mol) Temperature Range, °C 243-261 217-267 Phase Liquid
<b>Heat of:</b> Combustion, cal/gm 946 Explosion, cal/gm 946 Gas Volume, cc/gm 980 Formation, cal/gm 1098 Fusion, cal/gm 18.23				<b>Armor Plate Impact Test:</b> 60 mm Master Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness
<b>Specific Heat:</b> cal/gm/°C (e) $\frac{^{\circ}\text{C}}{\text{O}_\text{C}}$ $\frac{\text{O}_\text{C}}{^{\circ}\text{C}}$ -150 0.189 0 0.397 -100 0.330 50 0.415 -50 0.364 100 0.428				<b>500-lb General Purpose Bomb:</b> Plate Thickness, inches 1 1½ 1¾ 2
<b>Burning Rate:</b> cm/sec				<b>Bomb Drop Test:</b> <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b> Max Safe Drop, ft
<b>Thermal Conductivity:</b> cal/sec/cm/°C $2.9-3.9 \times 10^{-4}$				<b>500-lb General Purpose Bomb vs Concrete:</b> Height, ft Trials Unaffected Low Order High Order
<b>Coefficient of Expansion:</b> Linear, %/°C  <b>Volume, %/°C</b>				<b>1000-lb General Purpose Bomb v. Concrete:</b> Height, ft Trials Unaffected Low Order High Order
<b>Hardness, Mohr's Scale:</b>				
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc				
<b>Compressive Strength:</b> lb/inch <sup>2</sup>				
<b>Vapor Pressure:</b> (g) $^{\circ}\text{C}$ mm Mercury 188 3.25 205 7.45 216 11.55 223 15.80 231 27.0 249 41.0				

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<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cone</th> <th>Steel Cone</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Color:</th> <th>Colorless</th> </tr> </thead> <tbody> <tr> <td>Principal Uses:</td> <td>Explosive ingredient of mixtures used in bombs or large caliber projectiles</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Method of Loading:</th> </tr> </thead> <tbody> <tr> <td colspan="2">Pressed or cast depending on composition of mixture</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Loading Density: gm/cc</th> <th>Variable</th> </tr> </thead> </table> <table border="1"> <thead> <tr> <th colspan="2">Storage:</th> </tr> </thead> <tbody> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 12</td> </tr> <tr> <td>Compatibility Group</td> <td>Group D</td> </tr> <tr> <td>Exudation:</td> <td>None</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)</th> </tr> </thead> <tbody> <tr> <td>Temp. <math>^{\circ}\text{C}</math></td> <td>PA Impact Test 2 Kg Wt, inches</td> </tr> <tr> <td>25</td> <td>31</td> </tr> <tr> <td>75</td> <td>28</td> </tr> <tr> <td>100</td> <td>27</td> </tr> <tr> <td>150</td> <td>27</td> </tr> <tr> <td>175</td> <td>12</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Compatibility with Metals: (a)</th> </tr> </thead> <tbody> <tr> <td colspan="2">In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Entropy: (g)</th> </tr> </thead> <tbody> <tr> <td>cal/mol at <math>25^{\circ}\text{C}</math></td> <td>36.0</td> </tr> </tbody> </table>		Glass Cone	Steel Cone	Hole Volume		Hole Depth		Color:	Colorless	Principal Uses:	Explosive ingredient of mixtures used in bombs or large caliber projectiles	Method of Loading:		Pressed or cast depending on composition of mixture		Loading Density: gm/cc	Variable	Storage:		Method	Dry	Hazard Class (Quantity-Distance)	Class 12	Compatibility Group	Group D	Exudation:	None	Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)		Temp. $^{\circ}\text{C}$	PA Impact Test 2 Kg Wt, inches	25	31	75	28	100	27	150	27	175	12	Compatibility with Metals: (a)		In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.		Entropy: (g)		cal/mol at $25^{\circ}\text{C}$	36.0
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<b>Fragment Velocity: ft/sec</b> At 9 ft At $25\frac{1}{2}$ ft Density, gm/cc																																																			
<b>Blow (Relative to TNT):</b> Air: Peak Pressure Impulse Energy  Air, Confined: Impulse  Under Water: Peak Pressure Impulse Energy  Underground: Peak Pressure Impulse Energy																																																			

Ammonium NitrateSolubility of ammonium nitrate, grams in 100 grams (%) of: (e)

<u>Water</u>	<u>Alcohol</u>	<u>Acetic Acid</u>	<u>Nitric Acid</u>	<u>Pyridine</u>
0 118	20	2.5	16.6	0.0
20 192	40	5	27.0	0.39
40 297	60	7.5	80.9	5.8
60 421	78	10.5	101.0	20.7
80 580			120.0	31.6
100 671			125	

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Ohlsson and Norrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Ammonium nitrate is decomposed by strong alkalies with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References:<sup>3</sup>

- (a) Departments of the Army and the Air Force TM 9-1910/TQ 11a-1-34, Military Explosives, April 1955.
- (b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Ammonium Nitrate to Explosion, PATR No. 1658, 11 July 1947.
- (c) D. P. McDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.
- G. D. Clift and B. T. Federoff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.
- (f) R. J. Finkelstein and G. Gamov, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (g) George Feick, The Dissociation Pressure and Free Energy of Formation of Ammonium Nitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).
- (h) M. A. Cook and M. Taylor Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

<sup>3</sup>See footnote 1, page 10.

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Ammonium Nitrate

(1) Also see the following Picatinny Arsenal Technical Reports on Ammonium Nitrate:

0	1	2	3	4	5	6	7	8	9
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	1321	1602	1783	1094	1225	676	1947	938	1409
1290	1841		2183	1214	1455	946	2167	1008	
1720	1321			1234	1635	1106		1038	
1391				1504	1675	1696			
1431					1725				

Ammonium Perchlorate

<b>Composition:</b> %		<b>Molecular Weight:</b> (ClH <sub>4</sub> NO <sub>6</sub> ) 117.5
C	30.4	
H	11.9	
N	3.4	$\text{NH}_4\text{ClO}_4$
O	54.5	
<b>C/H Ratio</b>		
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	67	<b>Boiling Point:</b> °C
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	24	<b>Refractive Index, n<sub>D</sub>:</b>
Sample Wt, mg	24	n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub> n <sub>D<sub>30</sub></sub>
<b>Falling Pendulum Test:</b>		<b>Vibration Stability Test:</b>
Steel Shoe	Snap	cc/40 Hrs, at
Fiber Shoe	Unaffected	90°C
<b>Rifle Bullet Impact Test:</b> Trials	%	100°C 0.13
Explosions		120°C 0.20
Portals		135°C
Burned		150°C 0.32
Unaffected		
<b>200 Gram Bomb Sand Test:</b>		<b>200 Gram Bomb Sand Test:</b>
		Sand, gm 6.0
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm
1		Mercury Fulminate
5	435	Lead Azide 0.20
10		Tetryl 0.25
15		
20		
<b>75°C International Heat Test:</b>		<b>Ballistic Mortar, % TNT:</b>
% Loss in 48 Hrs		
<b>100°C Heat Test:</b>		<b>Trend Test, % TNT:</b>
% Loss, 1st 48 Hrs	0.02	
% Loss, 2nd 48 Hrs	0.00	<b>Plate Dent Test:</b>
Explosion in 100 Hrs	None	Method
		Condition
		Confined
		Density, gm/cc
		Brisance, % TNT
<b>Flammability Index:</b>		<b>Detonation Rate:</b>
<b>Hygroscopicity:</b> %		Confinement
<b>Volatility:</b>		Condition
		Charge Diameter, in.
		Density, gm/cc
		Rate, meters/second

Ammonium Perchlorate

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<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KG-3: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  Color: Colorless  <b>Principal Uses:</b> Explosive ingredient of mixtures used in pyrotechnics and as projectile filler.  <b>Method of Loading:</b> Pressed or cast depending on composition of mixture  <b>Loading Density:</b> gm/cc      Variable  <b>Storage:</b> Method      Dry  <b>Hazard Class (Quantity-Distance):</b> Class 9  <b>Compatibility Group:</b> Exudative      None  <b>Solubility in Water:</b> gm/100 cc saturated solution: <table><tr><td>0°C</td><td>12</td></tr><tr><td>25°C</td><td>20</td></tr><tr><td>60°C</td><td>39</td></tr><tr><td>100°C</td><td>88</td></tr></table> <b>Preparations:</b>  The perchlorates are prepared by the action of the acid on a suitable base; by the thermal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin).  <b>Heat of:</b> Formation, cal/gm      665	0°C	12	25°C	20	60°C	39	100°C	88
0°C	12								
25°C	20								
60°C	39								
100°C	88								

Ammonium PerchlorateOrigin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlesing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1259, [1871]). U. Alvisi treated a mixture of 76 parts of ammonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of ammonium perchlorate which were purified by recrystallization from hot water (German Patent, 103,993, 1893). A. Biocati mixed magnesium or calcium perchlorate with ammonium chloride and crystals of ammonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112,682, 1899).

References:<sup>4</sup>

- (a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PAIR No. 1372, 29 November 1943.
- (b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.
- (c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longmans, Green and Co., London, 1922, p. 306.
- (d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

0	1	3	4	5	6	2
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

<sup>4</sup>See footnote 1, page 10.

Baratol

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<b>Composition:</b> %		<b>Molecular Weight:</b>	125
Barium nitrate	67	Oxygen Balance: CO <sub>2</sub> %	-3
TNT	33	CO %	+13
C/H Ratio		<b>Density:</b> gm/cc	Cast 2.55
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	35	<b>Melting Point:</b> °C	
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
Picatinny Arsenal Apparatus, in.	11	<b>Boiling Point:</b> °C	
Sample Wt, mg	24	<b>Refractive Index,</b> n <sub>D</sub> <sup>20</sup>	n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>20</sup>
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Steel Shoe		90°C	
Fiber Shoe		100°C	
<b>Rifle Bullet Impact Test:</b> Trials	%	120°C	
Explosions		135°C	
Partials		150°C	
Burned		<b>200 Gram Bomb Sand Test:</b>	
Unaffected		Sand, gm	26.8
<b>Explosion Temperature:</b> °C Secs/ds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> /Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Ignites	385	Lod Azide	0.20
10		Tetryl	0.10
15		<b>Ballistic Mortar, % TNT:</b>	
20		<b>Treuzl Test, % TNT:</b>	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Plate Demol Test:</b> (a) 73:27	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		Method B	
% Loss, 2nd 48 Hrs		Condition Cast	
Explosion in 100 Hrs		Confined No	
<b>Flammability Index:</b>		Density, gm/cc 2.52	
<b>Hygroscopicity:</b> % 50°C, 90% RH	0.00	Brisance, % TNT 61	
<b>Volatility:</b>		<b>Detonation Rate:</b>	
		Confinement	
		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	

**AMCP 706-177****Baratol**

<b>Booster Sensitivity Test:</b> Condition Tetrol, gm 200 Wax, in. for 50% Detonation 0.32 Wax, gm Density, gm/cc 0.55	<b>Burnup/oxidation Equations:</b> Oxygen, atoms/sec. (Z/sec) Heat, Kilocalories/mole (ΔH, kcal/mol) Temperature Range, °C Phase																
<b>Heat of:</b> Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm 75/25 Baratol 2.6 (d)	<b>Armor Plate Impact Test:</b> 60 mm Mortar, mm profile 50% Inert, Velocity, ft/sec Aluminum Fineness																
<b>Specific Heat:</b> cal/grm/°C (d) 75/25 Baratol <table border="1"><tr><th>°C</th><th>°C</th></tr><tr><td>-75</td><td>0.152</td></tr><tr><td>0</td><td>0.147</td></tr><tr><td>25</td><td>0.160</td></tr><tr><td>50</td><td>0.229</td></tr><tr><td>75</td><td>0.260</td></tr><tr><td>95</td><td>0.213</td></tr><tr><td>100</td><td>0.171</td></tr></table>	°C	°C	-75	0.152	0	0.147	25	0.160	50	0.229	75	0.260	95	0.213	100	0.171	<b>500-lb General Purpose Bomb:</b> Plate Thickness, inches 1 1½ 2½ 3½
°C	°C																
-75	0.152																
0	0.147																
25	0.160																
50	0.229																
75	0.260																
95	0.213																
100	0.171																
<b>Burning Rate:</b> cm/sec.	<b>Bomb Drop Test:</b> <b>77, C900-1b Semi-Corner-Piercing Bomb vs Concrete:</b> Max Safe Drop, ft																
<b>Thermal Conductivity:</b> cal/sec/cm/°C	<b>500-lb General Purpose Bomb vs Concrete:</b> Height, ft Trials Unaffected Low Order High Order																
<b>Coefficient of Expansion:</b> Linear, %/°C Volume, %/°C	<b>1000-lb General Purpose Bomb vs Concrete:</b> Height, ft Trials Unaffected Low Order High Order																
<b>Hardness, Mohs' Scale:</b>																	
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc																	
<b>Compressive Strength:</b> lb/inch <sup>2</sup>																	
<b>Vapor Pressure:</b> °C mm Mercury																	

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<p><b>Fragmentation Test:</b></p> <p>50 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc</p> <p>Charge Wt, lb</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td style="text-align: center;">Glass Cones</td><td style="text-align: center;">Steel Cones</td></tr> <tr> <td style="text-align: center;">Hole Volume</td><td></td></tr> <tr> <td style="text-align: center;">Hole Depth</td><td></td></tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth	
Glass Cones	Steel Cones						
Hole Volume							
Hole Depth							
<p><b>Total No. of Fragments:</b></p> <p>For TNT</p> <p>For Subject HE</p>	<p><b>Color:</b></p>						
<p><b>3 inch HE, M43A1 Projectile, Lot KC-5:</b></p> <p>Density, gm/cc</p> <p>Charge Wt, lb</p>	<p><b>Principal Uses:</b> Bomb filler</p>						
<p><b>Total No. of Fragments:</b></p> <p>For TNT</p> <p>For Subject HE</p>	<p><b>Method of Loading:</b> Cast</p>						
<p><b>Fragment Velocity: ft/sec</b></p> <p>At 9 ft</p> <p>At 25½ ft</p> <p>Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b> 2.55</p>						
<p><b>Blast (Relative to TNT):</b></p> <p>Air:</p> <ul style="list-style-type: none"> <li>Peak Pressure</li> <li>Impulse</li> <li>Energy</li> </ul>	<p><b>Storage:</b></p> <table border="0"> <tr> <td style="text-align: center;"><b>Method</b></td> <td style="text-align: center;">Dry</td> </tr> </table>	<b>Method</b>	Dry				
<b>Method</b>	Dry						
<p>Air, Confined:</p> <ul style="list-style-type: none"> <li>Impulse</li> </ul>	<p><b>Hazard Class (Quantity-Distance)</b> Class 9</p>						
<p>Under Water:</p> <ul style="list-style-type: none"> <li>Peak Pressure</li> <li>Impulse</li> <li>Energy</li> </ul>	<p><b>Compatibility Group</b> Group I</p>						
<p><b>Underground:</b></p> <ul style="list-style-type: none"> <li>Peak Pressure</li> <li>Impulse</li> <li>Energy</li> </ul>	<p><b>Exudation</b></p>						
<p><b>Preparation:</b></p>	<p>The appropriate weight of barium nitrate heated to about 90°C is added to molten TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature.</p>						
<p><b>Origin:</b></p>	<p>Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.</p>						

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Baratol

References:<sup>5</sup>

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (b) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

<u>0</u>	<u>3</u>	<u>6</u>	<u>8</u>
2010	1783	2226	2138
2160	2233		

- (d) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

<sup>5</sup>See footnote 1, page 10.

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<b>Composition:</b> %		<b>Molecular Weight:</b>	111
Barium nitrate	50	Oxygen Balance: CO <sub>2</sub> %	-24
TNT	35	CO %	-7
Aluminum	15	<b>Density:</b> gm/cc	2.32
C/H Ratio		<b>Melting Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	30	<b>Freezing Point:</b> °C	
Sample Wt 20 mg		<b>Bulking Point:</b> °C	
Picatinny Arsenal Apparatus, in.	12	<b>Refractive Index,</b> n <sub>D</sub> n <sub>D</sub> n <sub>D</sub>	
Sample Wt, mg	22	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
<b>Friction Pendulum Test:</b> Steel Shoe		90°C	
Fiber Shoe		100°C	
<b>Rifle Bullet Impact Test:</b> Trials		120°C	
Explosions %		135°C	
Partials		150°C	
Burned			
Unaffected		<b>20G Grenade Shell Test:</b> Sand, g/m	39.8
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b>	
1		Mercury Fulminate	
5 Ignites	345	Lead Azide	0.20
10		Tetryl	0.10
15			
20		<b>Ballistic Mortar, % TNT:</b> (a)	96
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Treitz Test, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		<b>Plate Dent Test:</b>	
% Loss, 2nd 48 Hrs		Method	
Explosion in 100 Hrs		Condition	
		Confined	
<b>Flammability Index:</b>		Density, gm/cc	
<b>Hygroscopicity:</b> %		Brisance, % TNT	
<b>Volatility:</b>		<b>Detonation Rate:</b> (b)	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	2.32
		Rate, meters/second	5450

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT			
For Subject, HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Bomb filler	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Cast	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b> 2.32	
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	Dry
Peak Pressure			
Impulse			
Energy			
Air, Confined:			
Impulse			
Under Water:			
Peak Pressure			
Impulse			
Energy			
Underground:		<b>Preparation:</b>	
Peak Pressure		Procedure same as described under <u>Baratol</u> except aluminum is added to the barium nitrate-TNT molten mixture under agitation until uniformity in comparison is obtained.	
Impulse			
Energy			
<b>Booster Sensitivity Test:</b>		<b>(c)</b>	
Condition		Cast	
Tetryl, gm		100	
Wax, in. for 50% Detonation		0.86	
Density, gm/cc		2.32	
<b>Heat of:</b>			
Combustion, cal/gm		2099	
Explosion, cal/gm		1135	
Gas Volume, cc/gm		410	

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References:<sup>6</sup>

- (a) L. C. Smith and E. G. Kyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) G. L. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Burwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.
- (e) S. J. Lowell, Propagation of Detonation in Long and Narrow Columns of Explosives, PATR No. 2136, February 1955.

<sup>6</sup>See footnote 1, page 10.

Black Powder

<b>Composition:</b> %  Potassium nitrate 74.0 Sulfur 10.4 Charcoal 15.6  C/H Ratio	<b>Molecular Weight:</b> 84
	<b>Oxygen Balance:</b> CO <sub>2</sub> % -22 CO % - 2
	<b>Density:</b> gm/cc Variable
	<b>Melting Point:</b> °C
	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg  Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 16	<b>Boiling Point:</b> °C
	<b>Refractive Index:</b> n <sub>d</sub> n <sub>d</sub> n <sub>d</sub>
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.5 120°C 0.9 135°C 150°C
<b>Friction Pendulum Test:</b> Steel Shoe Snaps Fiber Shoe Unaffected  <b>Rifle Bullet Impact Test:</b> Trials %  Explosions Partially Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 8
	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Sensitive to igniting fuse
	<b>Ballistic Mortar, % TNT:</b> 50
	<b>Trenz Test, % TNT:</b> (a) 10
	<b>Plate Dot Test:</b> Method Condition Confined Density, gm/cc Brionce, % TNT
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.31  <b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc 1.6 Rate, meters/second 400
	<b>Flammability Index:</b>
	<b>Hygroscopicity:</b> % 26°C, 72% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51
<b>Volatility:</b>	

Black Powder

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>					
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones				
Density, gm/cc		Hole Volume					
Charge Wt, lb		Hole Depth					
<b>Total No. of Fragments:</b>		<b>Color:</b>					
For TNT		Black					
For Subject HE							
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b>					
Density, gm/cc		1. Igniter powder					
Charge Wt, lb		2. Time rings (fuzes)					
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>					
For TNT		1. Loose (granulated)					
For Subject HE		2. Pressed					
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>					
At 9 ft		psi $\times 10^3$					
At 25½ ft		25	50	60	65	70	75
Density, gm/cc		1.74	1.84	1.86	1.87	1.88	1.89
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>					
Air:		Method	Dry				
Peak Pressure		Hazard Class (Quantity-Distance)	Class 9				
Impulse		Compatibility Group	Group 0				
Energy		Exudation	None				
Air, Confined:		<b>100°C Vacuum Stability Test,</b>					
Impulse		cc gas/40 hrs:					
Under Water:		Initial Value	0.5				
Peak Pressure		After 2 hours at 65°C	0.86				
Impulse		After 2 hours at 65°C, 75% RH	1.46				
Energy		<b>Sensitivity to Electrostatic Discharge, Joules:</b>					
Underground:		(b)					
Peak Pressure		Unconfined	> 12.5				
Impulse		Confined	0.8				
Energy		<b>Compatibility with Metals:</b>					
<b>Initiating Efficiency:</b>		Dry - Compatible with all metals when moisture content is less than 0.20%.					
<b>Grams Required to Initiate</b>		Wet - Attacks all common metals except stainless steel.					
Igniter Comp K-32	2.0	<b>Heat of:</b>					
Igniter Comp K-29	2.3	Explosion, cal/gm	684				
		Gas Volume, cu/gm	271				

Preparation:

Willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is incorporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 6000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to canvas trays and dried in hot air ovens at 60°C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than #40 U. S. Sieve is not graphited.

**WARNING**

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References:<sup>7</sup>

- (a) Ph. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1926.
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.
- (c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

<sup>7</sup>See footnote 1, page 10.

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Black Powder

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	51	222	163	354	65	56	347	188	379
710	471	272	363	454	415	176	407	318	819
850	661	322	453	544	545	356	437	428	839
1010	901	472	843	554	605	686	547	558	849
1450	1111	492	1043	574	1145	746	757	598	859
	1241	582	1153	594	1275	1256	847	608	899
	1451	762	1243	654	1815	1316	1097	618	1259
	1541	872	1333	664	1885	1536	1737	698	1309
	1711	1022	1493	774	1905	1576	1797	838	1339
	1911	1622	1583	844	1915	1586	1807	898	1349
	1951	1712	1643	1114		1946	1827	1068	1589
	2051	1802	1813	1154				1388	1739
		1912	1843	1244				1528	1869
			1973	1504				1778	1889
								1808	
								1838	
								1928	
								2178	

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1,2,4-Butanetriol Trinitrate (BTTN) Liquid

<b>Composition:</b> C 19.9 H 2.9 N 17.5 O 59.7 C/H Ratio 0.13	<b>Molecular Weight:</b> ( $C_4H_7N_3O_9$ ) 241
<chem>O=[N+]([O-])C[C@H](O[N+](=O)[O-])[C@H](O[N+](=O)[O-])C</chem>	<b>Oxygen Balance:</b> CO, % -17 CO, % 10
	<b>Density:</b> gm/cc Liquid 1.52
	<b>Melting Point:</b> °C
	<b>Freezing Point:</b> °C
	<b>Boiling Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 58 Picatinny Arsenal Apparatus, in. $\leq 1$ Sample Wt 20 mg	<b>Refractive Index,</b> $n_D^0$ 1.4730 $n_M^0$ $n_K^0$
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at: 90°C 100°C 2.33 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 48.6
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Decomposes 230 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 1.5 % Loss, 2nd 48 hrs 1.2 Explosion in 100 Hrs None	<b>Torsil Test, % TNT:</b>
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> % (a) 100°F, 95% RH, 24 hrs 0.14	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in Density, gm/cc Rate, meters/second
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 46	

1,2,4-Butanetriol Trinitrate (BTTN) Liquid

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Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Yellow oil	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot K-2-S:</b>		<b>Principal Uses:</b> Explosive plasticizer for nitrocellulose	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density:</b> gm/cc	1.52
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		<b>Method:</b>	
Peak Pressure		<b>Hazard Class (Quantity-Distance)</b>	
Impulse			
Energy		<b>Compatibility Group</b>	
<b>Air, Confined:</b>			
Impulse		<b>Exudation</b>	
<b>Under Water:</b>			
Peak Pressure		Solubility in Water, gm/100 gm, rt:	(a)
Impulse		20°C	0.04
Energy		50°C	0.15
<b>Underground:</b>		Solubility of Water in, gm/100 gm:	(a)
Peak Pressure		at 25°C, ice:	0.04
Impulse		Ether	~
Energy		Alcohol	~
<b>Heat off:</b>	(a)	2:1 Ether:Alcohol	~
Combustion, cal/cm	114	Acetone	~
Explosion, cal/cm	14.7		
Gas Volume, cm³/cm	1.0	<b>Vicinity, compatibility:</b> (a)	

1,2,4-Butanetriol Trinitrate (BTTN) LiquidPreparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at 0°-5°C. When the agitation was completed, stirring was continued for one and one-half hours. The mixture was poured into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of ether. The combined ether extracts were washed with water, then with a 5% sodium bicarbonate solution and finally with water. The neutralized extract was dried with anhydrous calcium chloride and then the ether was evaporated. The yellow oil was dried in a vacuum desiccator over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriol was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium permanganate under mild conditions (Ber 27, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Quarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Naval Laboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

References:<sup>3</sup>

- (a) J. A. Gallagher, F. Macri, J. Bednarik, and P. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Factory Technical Report No. 19, 10 September 1948.
- (b) Also see the following Picatinny Arsenal Technical Reports on Butanetriol Trinitrate: 1755 and 1786.

<sup>3</sup>See footnote 1, page 10.

Composition A-3

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<b>Composition:</b> %		<b>Molecular Weight:</b>	227
RDX	91	Oxygen Balance: CO <sub>2</sub> %	-48
Nax	9	CO %	-23
		Density: gm/cc	12,000 psi
			1.65
<b>C/H Ratio</b>		<b>Melting Point:</b> °C	
		<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	100+	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		Refractive Index, n <sub>D</sub> <sup>20</sup>	
Picatinny Arsenal Apparatus, in.	16	n <sub>D</sub> <sup>25</sup>	
Sample Wt, mg	17	n <sub>D</sub> <sup>30</sup>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Steel Shoe	Unaffected	90°C	
Fiber Shoe	Unaffected	100°C	0.3
		120°C	0.6
		135°C	
		150°C	
<b>MMG Bullet Impact Test:</b> Trials	%	<b>200 Gram Bomb Sand Test:</b>	
Explosions	0	Sand, gm	51.5
Partials	0		
Burned	0		
Unaffected	100		
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.22*
5 Decomposes	250	Lead Azide	0.25*
10		Tetryl	
15		* Alternative initiating charges	
20		<b>Bellistic Mortar, % TNT:</b> (a) 13	
<b>75°C Intermittent Heat Test:</b>		<b>Treubl Test, % TNT:</b>	
% Loss in 48 Hrs		<b>Plate Dent Test:</b> (b)	
<b>100°C Heat Test:</b>		Method	B
% Loss, 1st 48 Hrs	0.15	Condition	Pressed
% Loss, 2nd 48 Hrs	0.15	Confined	No
Explosion in 100 Hrs	None	Density, gm/cc	1.61
		Brisance, % TNT	126
<b>Flammability Index:</b>	195		75
<b>Hygrosopicity:</b> % 30°C, 90% RH	0.0	<b>Detonation Rate:</b> (c)	
<b>Volatility:</b> 50°C, 15 days	0.03	Confinement	None
		Condition	Pressed
		Charge Diameter, in.	1.0
		Density, gm/cc	1.59
		Rate, meters/second	8100

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>
Density, gm/cc	1.62	Hole Volume	
Charge Wt, lb	2.102	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	White-buff	
For Subject HE	1138	<b>Principal Uses:</b>	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		HE, SAP, AP projectiles; Shaped Charges	
Density, gm/cc	1.64		
Charge Wt, lb	0.861		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT	514	Pressed	
For Subject HE	710		
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft	2800	3	12
At 25½ ft	2530	1.47	1.65
Density, gm/cc	1.61	<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		Method	
Air:		Dry	
Peak Pressure			
Impulse			
Energy			
Air, Confined:		<b>Lazard Class (Quantity-Distance)</b>	
Impulse		Class 9	
Under Water:		<b>Compatibility Group</b>	
Peak Pressure		Group I	
Impulse			
Energy		Exudation does not exude at 65°C when waxes melting sharply at or above 75°C are used.	
<b>Preparation:</b>			
A water slurry of RDX is heated to 100°C with agitation. Wax and a wetting agent are added and the mixture, under agitation, is cooled below the melting point of the wax. The wax coated RDX is collected on a filter and air dried at 75°C.			
<b>Effect of Temperature on</b>		<b>Fate of Detonation:</b>	
		(e)	
16 hrs at, °C	-54	21	
Density, gm/cc	1.51	1.51	
Rate, m/sec	7600	7620	
<b>Booster Sensitivity Test:</b>		(d)	
Condition		Pressed	
Tetryl, gm		100	
Wax, in. for 100% Detonation		1.70	
Density, gm/cc		1.62	
<b>Heat of:</b>			
Combustion, cal/gm		1210	

Composition A-3

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Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic wax, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References:<sup>9</sup>

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

(c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, dated 15 June 1949.

(e) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

0	1	2	3	4	5	6	7	8	9
1380	1451	1492	1493	1424	1325	1556	1637	1336	1639
1310	1761	2112		1614	1585	1936	1737	1388	2179
				1634	1595		1737	1743	
				2154	1715			1838	
					1835				
					2235				

<sup>9</sup>See footnote 1, page 10.

Composition B

<b>Composition:</b> %		<b>Molecular Weight:</b>	224
RDX	60	Oxygen Balance: CO <sub>2</sub> %	-43
TNT	40	CO %	10
Wax, added	1	Density: gm/cc	Cast 1.65
C/H Ratio		Melting Point: °C	(1) 78-80
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	75	Freezing Point: °C	
Sample Wt 20 mg		Bottling Point: °C	
Picatinny Arsenal Apparatus, in.	14	Refractive Index, n <sub>d<sup>20</sup></sub>	
Sample Wt, mg	19	n <sub>d<sup>20</sup></sub> n <sub>d<sup>25</sup></sub> n <sub>d<sup>30</sup></sub>	
Friction Pendulum Test:		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C	
Steel Shoe	Unaffected	100°C	0.7
Fiber Shoe	Unaffected	120°C	0.9
Rifle Bullet Impact Test: Trials		135°C	
Explosions	%	150°C	11+
Partials	3	200 Gram Bomb Sand Test:	
Burned	13	Sand, gm	54.0
Unaffected	4	Sensitivity to Initiation:	
	80	Minimum Detonating Charge, gm	
Explosion Temperature: °C		Mercury Fulminate	0.22*
Seconds, 0.1 (no cap used)	526	Lead Azide	0.20*
1	368	* Tetryl	
5 Decomposes	278	* Alternative initiating charges	
10	255	Ballistic Mortar, % TNT: (a)	133
15	> 250	Treitz Test, % TNT: (b)	130
20	> 250	Plate Dent Test: (c)	
75°C International Heat Test: % Loss in 48 Hrs		Method	B
100°C Heat Test: % Loss, 1st 48 Hrs	0.2	Condition	Cast
% Loss, 2nd 48 Hrs	0.2	Confined	No
Explosion in 100 Hrs	None	Density, gm/cc	1.71
Chrommobility Index:	177	Brisance, % TNT	132
Hygroscopicity: % 30°C, 90% RH	0.02		
Volatility:		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.68
		Rate, meters/second	7840

Composition B

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Booster Sensitivity Test:		(d)	Decomposition Equation:	
Condition	Cast		Oxygen, atoms/sec (Z/sec)	
Tetryl, gm	100		Heat, kilocalorie/mole (ΔH, kcal/mol)	
Wax, in. for 50% Detonation	1.40		Temperature Range, °C	
Wax, gm			Phase	
Density, gm/cc	1.68			
Heat of:		(e)	Armor Plate Impact Test:	
Combustion, cal/gm	2790		(e)	
Explosion, cal/gm	1240		60 mm Mortar Projectile:	
Gas Volume, cc/gm			50% Inert, Velocity, ft/sec	209
Formation, cal/gm			Aluminum Fineness	
Fusion, cal/gm	(1)	8.0		
Specific Heat: cal/gm/°C (1)			500-lb General Purpose Bomb:	
°C	°C		Plate Thickness, inches	
-75	0.235	75	Trials	% Inert
0	0.220	85	4	100
25	0.251	90	6	50
50	0.305	100	2	0
			0	
Burning Rate:			Bomb Drop Test:	
cm/sec			T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:	
Thermal Conductivity:			Max Safe Drop, ft	
cal/sec/cm/°C			500-lb General Purpose Bomb vs Concrete:	
Coefficient of Expansion:			No Seal	Seal
Linear, %/°C			Height, ft	4000
Volume, %/°C			Trials	65
Hardness, Mohs' Scale:			Unaffected	58
Young's Modulus:			Low Order	2
E', dynes/cm <sup>2</sup>			High Order	5
E, lb/inch <sup>2</sup>				1
Density, gm/cc				
Compressive Strength: lb/inch <sup>2</sup> (b)		1610-2580	1000-lb General Purpose Bomb vs Concrete:	
Density, gm/cc		1.68	Height, ft	
Vapor Pressure:			Trials	
°C	mm Mercury		Unaffected	
			Low Order	
			High Order	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		(g)	(h)
Density, gm/cc	1.65	Glass Cones	Steel Cones
Charge Wt, lb	2.187	Hole Volume	178 162
<b>Total No. of Fragments:</b>		<b>Hole Depth</b>	
For TNT	703	125	148
For Subject HE	998		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Color:</b>	
Density, gm/cc	1.67	Yellow-brown	
Charge Wt, lb	0.662		
<b>Total No. of Fragments:</b>		<b>Principal Uses:</b>	
For TNT	514	Fragmentation bombs, HE projectiles, grenades, shaped charges	
For Subject HE	701		
<b>Fragment Velocity: ft/sec</b>		<b>Method of Loading:</b>	
At 9 ft	2940	C-10	
At 25½ ft	2680		
Density, gm/cc	1.68	<b>Loading Density: gm/cc</b>	
		1.68	
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:	(f)	Method	
Peak Pressure	110	Dry	
Impulse	110		
Energy	116	<b>Hazard Class (Quantity-Distance):</b>	
Air, Confined:		Class 9	
Impulse	75		
Under Water:		<b>Compatibility Group:</b>	
Peak Pressure	110	Group I	
Impulse	108		
Energy	121	Exudation Very slight when stored at 71°C	
Underground:		<b>Origin:</b>	
Peak Pressure	104	RDX Composition B was developed by the British between World War I and World War II. It was standardized by the United States early in World War II.	
Impulse	97		
Energy		<b>Effect of Temperature on Rate of Detonation:</b>	
Crater radius cuted	107	16 hrs at, °C	-54 24
		Density, gm/cc	1.69 1.69
		Rate, m/sec	7720 7660
		<b>Bulk Modulus at Room Temperature (25°-30°C):</b>	
		% Wax in Comp B	1 2 3
		Dynes/cm² x 10⁻¹⁰	5.10 3.5% 2.3%
		Density, gm/cc	1.72 1.70 1.7%
		<b>Viscosity, poises:</b>	
		Temp, °C	3.1
		°F	2.7

Composition BCompatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten T<sup>MM</sup> melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is cast directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition is complete, stirring is continued for one-half hour.

References:<sup>10</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Divisions 2 and 8, NDRC, Report on HEV and Tritonal, OSRD Report No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.
- (h) Eastern Laboratory du Pont, Investigation of Cavity Effect, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.
- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PAIR No. 2353, November, 1950.

<sup>10</sup>See footnote 1, page 10.

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(j) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on RDX Composition B:

0	1	2	3	4	5	6	7	8	9
1360	1211	1402	1313	1224	1325	1466	1207	1338	1339
1530	1451	1482	1433	1424	1435	1476	1437	1388	1379
2100	2131	1592	1803	1944	1585	1556	1457	1438	1469
2160	2151		1983	2004	1595	1756	137	1458	1819
2190			2053	2104	1865	1956	1797	1688	1719
			2063		1885	223	2007	1728	
			2103		2055		2147	1828	
			2233		2125			1838	
					2155			1978	
					2175			2008	
					2235			2138	
								2168	

(l) C. Lanchitz, W. Beach and R. VaJicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

Composition B, Desensitized

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Composition:	I*	II**	Molecular Weight:	I*	II**
%			See Cyclonite	See Comp B	
RDX	60	55.2			
TNT	40	40.0			
Wax, added, (Stanclind or Aristowax, 165°/170°F)	5		CO %	See Cyclonite	See Comp B
Vinylseal (MA28-14), added	2		CO %	See Cyclonite	See Comp B
Vistanex (Bl20)		1.2	Density: gm/cc	Cast	1.65
Albacore Wax		3.6			1.65
C/H Ratio			Melting Point: °C		
Impact Sensitivity, 2 Kg Wt:	I*	II**	Freezing Point: °C		
Bureau of Mines Apparatus, cm	95		Boiling Point: °C		
Sample Wt 20 mg			Refractive Index, n <sub>D</sub> <sup>20</sup>		
Picatinny Arsenal Apparatus, in.	14	13	n <sub>D</sub> <sup>20</sup>		
Sample Wt, mg	17	16	n <sub>D</sub> <sup>20</sup>		
Friction Pendulum Test:			Vacuum Stability Test:	I*	II**
Steel Shoe	Unaffected		cc/40 Hrs, at		
Fiber Shoe	Unaffected		90°C		
Rifle Bullet Impact Test: Trials			100°C		
Explosions %	I*	II**	120°C	0.99	0.92
Partials	0	0	135°C		
Burned	5	0	150°C	11+	11+
Unaffected	95	100	200 Gram Bomb Sand Test:	I*	II**
Explosion Temperature: °C	I*	II**	Sand, gm	52.7	55.0
Seconds, 0.1 (no cap used)					
1			Sensitivity to Initiation:	I*	II**
5 Decomposes	260	270	Minimum Detonating Charge, gm		
10			Mercury Fulminate		
15			Lead Azide	0.22	0.26
20			Tetryl		
75°C International Heat Test:			Ballistic Mortar, % TNT:		
% Loss in 48 Hrs			Treuzl Test, % TNT:		
10°C Heat Test:	I*	II**	Plate Dent Test:		
% Loss, 1st 48 Hrs	0.05	0.12	Method		
% Loss, 2nd 48 Hrs	0.19	0.18	Condition		
Explosion in 100 Hrs	None	None	Confined		
Flammability Index:			Density, gm/cc		
Hygroscopicity: % 30°C, 90% RH	0.00	0.00	Brisance, % TNT		
Volatility:	Nil	Nil	Detonation Rate:		
			Confinement		
			Condition		
			Charge Diameter, in.		
			Density, gm/cc		
			Rate, meters/second		

\*Desensitized Comp B, designated I, uses emulsified wax.

\*\*Desensitized Comp B, designated II, uses coated RDX.

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Composition B, Desensitized

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Gloss Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			
For TNT		<b>Color:</b>	
For Subject HE		Yellow-brown	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>			
Density, gm/cc	1.65	I*	II**
Charge Wt, lb	0.87	1.65	
<b>Total No. of Fragments:</b>			
For TNT	514	51'	
For Subject HE	609	659	
<b>Fragment Velocity: ft/sec</b>		<b>Method of Loading:</b>	
At 9 ft		Cast	
At 25½ ft			
Density, gm/cc		<b>Loading Density: gm/cc</b>	
		1.65	
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	
Peak Pressure		Dry	
Impulse			
Energy			
Air, Confined:		<b>Hazard Class (Quantity-Distance):</b>	
Impulse		Class 9	
Under Water:		<b>Compatibility Group:</b>	
Peak Pressure		Group I	
Impulse			
Energy		<b>Exudation:</b>	
Underground:			
Peak Pressure		<b>Viscosity, poises:</b>	
Impulse		I*	II**
Energy		Temp, 83°C	3.5
		95°C	2.6
			3.1
			2.7
<b>References:</b>			
(a) See the following Picatinny Arsenal Technical Reports on RDX Composition B, Desensitized:			
		1	3
		2151	1313
		2	6
		1435	1750
		2053	1565
*Desensitized Comp B, designated I, uses emulsified wax.			
**Desensitized Comp B, designated II, uses coated RDX.			

Composition C

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<b>Composition:</b> %		<b>Molecular Weight:</b>
RDX	88.3	Oxygen Balance: CO <sub>2</sub> % CO %
Plasticizer, non-explosive	11.7*	Density: gm/cc
*Nonexplosive oily plasticizer containing 0.6% lecithin.		Melting Point: °C
C/H Ratio		Freezing Point: °C
Impact Sensitivity, 2 kg Wt: Bureau of Mines Apparatus, cm	100+	Boiling Point: °C
Sample Wt 20 mg		Refractive Index, n <sub>20</sub> <sup>20</sup>
Picatinny Arsenal Apparatus, in. Sample Wt, mg		n <sub>20</sub> n <sub>25</sub> n <sub>30</sub>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		Vacuum Sensitivity Test: cc/40 Hrs, at 90°C
Rifle Bullet Impact Test: Trials		100°C 0.3
Explosions	%	120°C 0.7
Partials	0	135°C
Burned	0	150°C
Unaffected	100	200 Gram Bomb Sand Test: Sand, gm 46.5
<b>Exploding Temperature:</b> °C Seconds, 0.1 (no cap used)		Sensitivity to Initiation: Minimum Detonating Charge, gm
1		Mercury Fulminate
5 Decomposes	285	Lead Azide 0.25
10		Tetryl 0.11
15		
20		
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		Ballistic Mortar, % TNT: (a) 120
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Treuzzi Test, % TNT:
<b>Flammability Index:</b>		Plate Dent Test: Method A Condition Hand Tamped
<b>Hygroscopicity:</b> % 30°C, 95% RH 0.25		Confined Yes
<b>Velocity:</b> 25°C, 5 days 0.00		Density, gm/cc 1.58 Brionce, % TNT 112
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

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### Composition C

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91:  Density, gm/cc Charge Wt, lb	<b>Shaped Charge Effectiveness, TNT = 100:</b>	
	(f)	(g)
	Gloss Cones	Steel Cones
Hole Volume	113	114
Hole Depth	101	111
<b>Total No. of Projectiles:</b>  For TNT For Subject HE	<b>Color:</b> White	
3 inch HE, M42A1 Projectile, Lot KC-8:  Density, gm/cc Charge Wt, lb	<b>Principal Uses:</b> Plastic demolition explosive	
<b>Total No. of Projectiles:</b>  For TNT For Subject HE	<b>Method of Loading:</b> Hand tamped	
<b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Loading Density:</b> gm/cc 1.49	
<b>Blow (Relative to TNT):</b>  Air Peak Pressure Impulse Energy	<b>Storage:</b>	
Air, Confined: Impulse	<b>Method:</b> Dry	
Under Water: Peak Pressure Impulse Energy	<b>Hazard Class (Quantity-Distance):</b> Class 9	
Underground: Peak Pressure Impulse Energy	<b>Compatibility Group:</b> Group I	
	<b>Exudation:</b> Exudes above 40°C	
	<b>Plasticity:</b>	
	Below 0°C	Brittle (0°C)
	0-40°C	Plastic
	Above 40°C	Exudes (40°C)
	<b>References:</b>	
	See references for Composition C-4.	

Composition C-2

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<b>Composition:</b> %	<b>Molecular Weight:</b>	
RDX            78.7	<b>Oxygen Balance:</b>	
TNT            5.0	CO <sub>2</sub> %	
DNT            12.0	CO %	
MFT            2.7	<b>Density:</b> gm/cc	
NC            0.6	<b>Melting Point:</b> °C	
Solvent        1.0	<b>Freezing Point:</b> °C	
<b>C/H Ratio</b>	<b>Boiling Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm            90	<b>Refractive Index, n<sub>D</sub><sup>20</sup>:</b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>	
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C            2.0 120°C            9.0 135°C 150°C	
<b>Rifle Bullet Impact Test:</b> Trials Explosions        % Partials        20 Burned        0 Unaffected      80	<b>200 Gram Bomb Shock Test:</b> Sand, gm            47.5	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Decomposes    285 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide            0.25 Tetryl            0.10	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b> (a)    126	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs            1.8 % Loss, 2nd 48 Hrs            1.4 Explosion in 100 Hrs        None	<b>Tread Test, % TNT:</b>	
<b>Flammability Index:</b> 178	<b>Plate Dent Test:</b> (c) Method            B Condition        Hand tamped Confined        No Density, gm/cc    1.52 Brisance, % TNT    111	
<b>Hygroscopicity:</b> % 30°C, 95% RH    0.55	<b>Detonation Rate:</b> (d) Confinement        None Condition        Hand tamped Charge Diameter, in.    1.0 Density, gm/cc    1.57 Rate, meters/second    7660	
<b>Volatility:</b> 25°C, 5 days    0.00		

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 Inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cores      Steel Cores Hole Volume Hole Depth  <b>Color:</b> White	
	<b>Principal Use:</b> Plastic demolition explosive	
	<b>Method of Loading:</b> Hand tamped	
	<b>Loading Density:</b> gm/cc      1.57	
	<b>Storage:</b>  Method      Dry	
	<b>Hazard Class (Quantity-Distance)</b> Class 9	
	<b>Compatibility Group</b> Group I	
	<b>Exudation</b> Volatilizes above 52°C	
	<b>Plasticity:</b>  Below 0°C      Plastic (-30°C) 0-40°C      Plastic above 40°C      Hard (52°C)*	
	<i>*Due to volatilization of plasticizer.</i>	
<b>References:</b>  See references for Composition C-4.		

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Composition C-3

<b>Composition:</b> %		<b>Molecular Weight:</b>
RDX	77	Oxygen Release: CO <sub>2</sub> % CO %
Tetryl	3	
TNT	4	
DNT	10	<b>Density:</b> gm/cc
NFT	5	
NC	1	<b>Melting Point:</b> °C
<b>C/H Ratio</b>		<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	100+	<b>Boiling Point:</b> °C
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	14	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>
Sample Wt, mg	33	n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub> n <sub>D<sub>30</sub></sub>
<b>Friction Pendulum Test:</b> Steel Shoe	Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at
Fiber Shoe	Unaffected	90°C
<b>80% Bullet Impact Test:</b> Trials		100°C 1.21
Explosions	%	120°C 11+
Partials	40	135°C
Burned	0	150°C
Unaffected	60	<b>2x 2 Gram Bomb Shock Test:</b> Sand, gm 53.1
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm
1		Mercury Fulminate
5 Decomposes	280	Lead Azide 0.20
10		Tetryl 0.08
15		
20		
<b>75°C International Heat Test:</b> % Loss in 1/8 Hrs		<b>Ballistic Mortar, % TNT:</b> (a) 126
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	3.20	<b>Tread Test, % TNT:</b> (b) 117
% Loss, 2nd 48 Hrs	1.63	
Explosion in 100 Hrs	None	<b>Plate Dent Test:</b> (c) Method B
<b>Flammability Index:</b>		Condition Hand tamped
<b>Hygroscopicity:</b> % 30°C, 95% RH	2.4	Confined No
<b>Volatility:</b>	25°C, 5 days	Density, gm/cc 1.57
		Brisance, % TNT 118
		<b>Detonation Rate:</b> (d) Confinement None
		Condition Hand tamped
		Charge Diameter, in. 1.0
		Density, gm/cc 1.60
		Rate, meters/second 7625

Composition C-3

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>
Density, gm/cc	1.58	Hole Volume	
Charge Wt, lb	2045	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Yellow	
For Subject HE	944		
<b>3 Inch HE, M43A1 Projectile, Lot KC-5:</b>		<b>Principal Use:</b>	
Density, gm/cc	1.60	Plastic demolition explosive	
Charge Wt, lb	0.842		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT	514	Hand tamped	
For Subject HE	671		
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc:</b>	
At 9 ft		1.58	
At 23½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		<b>Method:</b>	
Peak Pressure	105	Dry	
Impulse	109		
Energy			
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance)</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group</b>	
Peak Pressure		Group I	
Impulse			
Energy			
<b>Underground:</b>		<b>Exudation</b>	
Peak Pressure		Exudes at 77°C	
Impulse			
Energy			
		<b>Plasticity:</b>	
		Below 0°C	Hard (-29°C)
		0-40°C	Plastic
		Above 40°C	Exudes (77°C)
<b>Booster Sensitivity Test:</b>		<b>(h)</b>	
		Condition	Pressed
		Tetryl, gm	100
		Wax, in. for 50% Detonation	1.36
		Density, gm/cc	1.62
<b>References:</b>			
See references for Composition C-4.			

Composition C-4

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Composition:		Molecular Weight:
%		
RDX	91	
Plasticizer, non-explosive	9%	
* Contains polyisobutylene 2.1%; motor oil 1.6% and di(2-ethylhexyl) sebacate 5.3%.		
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	100+	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	19	
Sample Wt, mg	27	
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Felt Shoe	Unaffected	
Rifle Bullet Impact Test: Trials		
Explosions %	0	
Partials %	0	
Burned %	20	
Unaffected %	80	
Explosion Temperature: °C		
Seconds, 0.1 (no cap used)		
1		
5	290	
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		
100°C Heat Test:		
% Loss, 1st 48 Hrs	0.13	
% Loss, 2nd 48 Hrs	0.00	
Expl. in 100 Hrs	None	
Flammability Index:		
Hygroscopicity: % 30°C, 95% RH	Nil	
Volatility:		
Oxygen Balance:		
CO <sub>2</sub> %		
CO %		
Density: gm/cc		
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n <sub>D</sub> <sup>20</sup>		
n <sub>D</sub> <sup>25</sup>		
n <sub>D</sub> <sup>28</sup>		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C	0.26	
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm	55.7	
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide	0.20	
Tetryl	0.10	
Ballistic Meter, % TNT: (a)	130	
Tread Test, % TNT:		
Plate Dent Test: (c)		
Method	E	
Condition	Hand tamped	
Confined	No	
Density, gm/cc	1.60	
Brisance, % TNT	115	
Detonation Rate: (d)		
Confinement	None	
Condition	Hand tamped	
Charge Diameter, in.	1.0	
Density, gm/cc	1.59	
Rate, meters/second	8040	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cores
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Light brown	
For Subject HE			
<b>3 Inch HE, M42A1 Projectile, Lot KC-3:</b>		<b>Principal Uses:</b> Plastic demolition explosive	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Hand tamped	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		1.60	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	
Peak Pressure		Dry	
Impulse			
Energy			
Air, Confined:		<b>Hazard Class (Quantity-Distance):</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group:</b>	
Peak Pressure		Group I	
Impulse			
Energy		<b>Exudation:</b>	
		None at 77°C	
		<b>Effect of Temperature on Rate of Detonation:</b> (1)	
		16 hrs at, °C	-54
		Density, gm/cc	21
		Rate, m/sec	1.36
			7020
			7040
<b>Plasticity:</b>			
Below 0°C		Plastic (-57°C)	
0-40°C		Plastic	
Above 40°C		Plastic (T°C)	

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDX is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item ammunition.

Composition C-4 is prepared by hand kneading and rolling, or in a Schrader Bowl mixer, RDX of 4 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60°C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts water, and 4 parts 95% alcohol, heated to 50°C. After addition of Composition C-3 is complete, the solution is heated to 80°C and maintained at this temperature for 15 minutes.

References:<sup>11</sup>

- (a) Committee of Div 2 and 8, Report on HbX and Tritonal, OSRD No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (e) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- (f) M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (h) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.
- (i) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDPC Contract W-672-ORD-5723.
- (j) L. C. Smit and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetralin in Boosters, NOL Memo 10,303, 15 June 1949.

<sup>11</sup>See footnote 1, page 10.

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Compositions C, C-2, C-3, C-4

(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2303, November 1956.

(j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

	0	1	2	3	4	5	6	7	8	9
<u>Comp C</u>	1260			1293					1518	
									1438	
<u>Comp C-2</u>				1293					1518	
<u>Comp C-3</u>		1611	1713	2154	1595	1416	1416	1797	1518	
					1695	1556			2028	
					1885	1766				
<u>Comp C-4</u>						1766	1907	1828	1819	
									1958	

Copper Chlorotetrasole

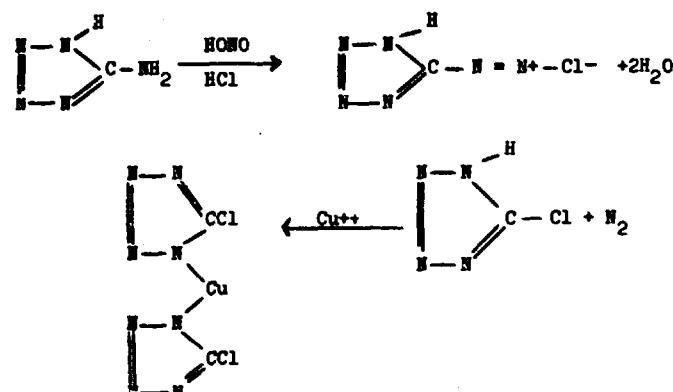
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<b>Composition:</b> %	<b>Molecular Weight:</b> ( $\text{CuC}_2\text{N}_2\text{Cl}_2$ ) 271
C 8.9	
N 41.5	
Cl 26.2	
Cu 23.4	
C/H Ratio	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg	<b>Oxygen Balance:</b> $\text{CO}_2$ % -30 $\text{CO}$ % -18
Picotinny Arsenal Apparatus, in. 1; (1 lb wt) 3 Sample Wt, mg 9	<b>Density:</b> gm/cc 2.04
<b>Friction Pendulum Test:</b> Steel Shoe Exploded Fiber Shoe Exploded	<b>Melting Point:</b> °C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>Frosting Point:</b> °C
<b>Explosion Temperature:</b> °C Seconds, 0.1 (nu. cap used) 1 5 305 10 15 20	<b>Boiling Point:</b> °C <b>Refractive Index:</b> $n_{D}^{20}$ $n_{D}^{25}$ $n_{D}^{28}$
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 2.67 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	<b>200 Gram Bomb Sand Test: (f)</b> Sand, gm 27.4 25.3 BLACK powder fuse 17.0
<b>Flammability Index:</b>	<b>Sensitivity to Initiators:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 0.30 Tetryl 0.10
<b>Hygroscopicity:</b> % 30°C, 90% RH 3.11	<b>Ballistic Mortar, % TNT:</b>
<b>Volatility:</b>	<b>Trendz Test, % TNT:</b>
	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-8: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Hole Volume</th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Color:</th> <th>Elce</th> </tr> </thead> <tbody> <tr> <td>Principal Uses:</td> <td>Primary explosive</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Method of Loading:</th> <th>Pressed</th> </tr> </thead> <tbody> <tr> <td>Loading Density: gm/cc</td> <td>psi <math>\times 10^3</math> (c)</td> </tr> <tr> <td>10</td> <td>20</td> <td>40</td> <td>70</td> </tr> <tr> <td>1.49</td> <td>1.63</td> <td>1.74</td> <td>1.86</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Storage:</th> </tr> <tr> <th>Method</th> <th>Wet</th> </tr> </thead> <tbody> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group N</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Stab Sensitivity:</th> </tr> <tr> <th>Density</th> <th>Firing Point (inch-ounces)</th> </tr> <tr> <th>gm/cc</th> <th>0%</th> <th>50%</th> <th>100%</th> </tr> </thead> <tbody> <tr> <td>1.49</td> <td>9</td> <td>11</td> <td>15</td> </tr> <tr> <td>1.63</td> <td>8.5</td> <td>10</td> <td>12</td> </tr> <tr> <td>1.74</td> <td>6</td> <td></td> <td>9</td> </tr> <tr> <td>1.86</td> <td>4</td> <td></td> <td>6</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Heat of:</th> </tr> <tr> <td>Explosion, cal/gm</td> <td>432</td> </tr> </thead> <tbody> <tr> <td colspan="2"><u>Specific Heat, cal/gm/<math>^{\circ}</math>C</u></td> </tr> <tr> <td>Temp range 0<math>^{\circ}</math>-30<math>^{\circ}</math>C</td> <td>0.155</td> </tr> <tr> <td>Wt of sample, gm</td> <td>0.8910</td> </tr> </tbody> </table>		Hole Volume	Glass Cones	Steel Cones	Hole Depth			Color:	Elce	Principal Uses:	Primary explosive	Method of Loading:	Pressed	Loading Density: gm/cc	psi $\times 10^3$ (c)	10	20	40	70	1.49	1.63	1.74	1.86	Storage:		Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group N	Exudation	None	Stab Sensitivity:		Density	Firing Point (inch-ounces)	gm/cc	0%	50%	100%	1.49	9	11	15	1.63	8.5	10	12	1.74	6		9	1.86	4		6	Heat of:		Explosion, cal/gm	432	<u>Specific Heat, cal/gm/<math>^{\circ}</math>C</u>		Temp range 0 $^{\circ}$ -30 $^{\circ}$ C	0.155	Wt of sample, gm	0.8910
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Wt of sample, gm	0.8910																																																																				

Preparation: (a)

Five grams of 5-aminotetrazole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated HCl. Enough kerosene or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately  $1/4$ " thick on the surface. With only moderate stirring and external cooling to  $10^{\circ}$ - $15^{\circ}$ C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 1 gm of cupric chloride in a minimum amount of water is added all at once, and stirring is continued for about 1 hour. The reaction mixture is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water, alcohol, and ether; and dried - giving a yield of 6 grams or  $7\frac{1}{2}\%$ .

Origin:

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stolle (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

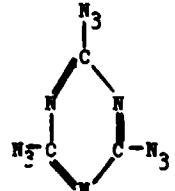
References:<sup>12</sup>

- (a) R. J. Gaughan and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.
- (b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances for Application in Ammunition, PATR No. 2179, May 1955.
- (c) A. C. Forsyth, Pfc. S. Krasner and R. J. Gaughan, Development of Optimum Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Compounds, PATR No. 2146, February 1955.

<sup>12</sup>See footnote 1, page 10.

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Cyanuric Triazide

<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>3</sub> N <sub>12</sub> ) 204
C 17.6	Oxygen Balance: CO <sub>2</sub> % -47.1
N 82.4	CO % -23.5
	<b>Density:</b> gm/cc <b>Crystal</b> 1.54
C/H Ratio	<b>Melting Point:</b> °C 94
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 1 kg wt 7 Sample Wt 20 mg	<b>Freezing Point:</b> °C
Picatinny Arsenal Apparatus, in. Sample Wt, mg	<b>Boiling Point:</b> °C
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Refractive Index,</b> n <sub>D</sub> n <sub>D</sub> n <sub>D</sub>
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 125°C 150°C
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 252 1 5 10 15 20	<b>200 Gram Bomb Sand Test:</b> Sand, gm 32.2
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate - Lead Azide 0.20 Tetryl 0.10
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>Flammability Index:</b>	<b>Troux Test, % TNT:</b>
<b>Hygroscopicity:</b> %	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Volatility:</b> Decomposes above 100°C	<b>Detonation Rate:</b> Confinement - Condition - Charge Diameter, in. 0.3 Density, gm/cc 1.15 Rate, meters/second 5550-5600

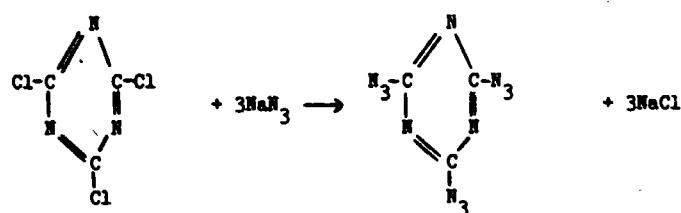
Cyanuric Triside

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<b>Fragmentation Test:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>	
Density, gm/cc	Gloss Cones      Steel Cones
Charge Wt, lb	Hole Volume Hole Depth
<b>Total No. of Fragments:</b>	
For TNT	Color:
For Subject HE	Colorless
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>	
Density, gm/cc	Principal Uses: Not used because of difficulty
Charge Wt, lb	in controlling sensitivity.
<b>Total No. of Fragments:</b>	
For TNT	Method of Loading: Pressed
For Subject HE	
<b>Fragment Velocity: ft/sec</b>	
At 9 ft	Loading Density: gm/cc
At 25½ ft	At 200 atmospheres      1.4
Density, gm/cc	At 800 atmospheres      1.5
<b>Wet (Relative to TNT):</b>	
Air:	
Peak Pressure	Storage:
Impulse	Method
Energy	Hazard Class (Quantity-Distance)      Class 9
Air, Confined:	
Impulse	Compatibility Group
Under Water:	
Peak Pressure	Exudation      None
Impulse	
Energy	
<b>Underground:</b>	
Peak Pressure	
Impulse	
Energy	

Cyanuric TriazidePreparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium azide:



Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triazide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS 51, 268 (1887)) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium azide (Ref b) Taylor and Rinkenbach prepared cyanuric triazide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead azide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

Formation, cal/gm -1090 to -1138

References:<sup>13</sup>

- (a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
- (b) Ott and Chase, Ber 54, 179 (1921).
- (c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923).
- Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

<sup>13</sup>See footnote 1, page 10.

Cyclonite\* (RDX)

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<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>3</sub> H <sub>6</sub> N <sub>6</sub> O <sub>6</sub> ) 222
C 16.3	O <sub>2</sub> N—N—CH <sub>2</sub>
H 2.7	H <sub>2</sub> C
N 37.8	CH <sub>2</sub>
O 43.2	N—NO <sub>2</sub>
C/H Ratio 0.395	
<b>Impact Sensitivity, 3 Kg Wt:</b> Bureau of Mines Apparatus, cm 32	<b>Density:</b> gm/cc <b>Crystal</b> 1.82
Sample Wt 20 mg	<b>Melting Point:</b> °C 204
Picatinny Arsenal Apparatus, in. 8	<b>Freezing Point:</b> °C
Sample Wt, mg 18	<b>Boiling Point:</b> °C
<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe Unaffected	<b>Refractive Index, n<sub>D</sub>:</b> n <sub>D</sub> n <sub>20</sub> n <sub>50</sub>
<b>RMS Bullet Impact Test:</b> Trials % Explosions 100 Partials 0 Burned 0 Unaffected 0	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.7 120°C 0.9 135°C - 150°C 2.5
<b>200 Gram Bomb Sand Test:</b> Sand, gm 60.2	<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm:</b> Mercury Fulminate 0.19* Lead Azide 0.05* Tetryl - * Alternative initiating charges.
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 405 1 316 5 Decomposes 260 10 240 15 235 20 -	<b>Ballistic Mortar, % TNT: (a)</b> 150 <b>Tread Test, % TNT: (b)</b> 157
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.03	<b>Plate Dent Test: (c)</b> <b>Method</b> A <b>Condition</b> Pressed <b>Confined</b> Yes <b>Density, gm/cc</b> 1.50 <b>Prisance, % TNT</b> 135
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	<b>Detonation Rate:</b> <b>Confinement</b> None <b>Condition</b> Pressed <b>Charge Diameter, in.</b> 1.0 <b>Density, gm/cc</b> 1.65 <b>Rate, meters/second</b> 8180
<b>Flammability Index:</b> (d) 278	
<b>Hygroscoicity:</b> % 25°C, 100% RH 0.02	
<b>Volatility:</b> Nil	

\*Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

Booster Sensitivity Test:				Decomposition Equation: $(1) \quad 10^{18.5}$			
Condition	Tetryl, gm	Oxygen, atoms/sec (Z/sec)					
Tetryl, gm	Wax, in. for 50% Detonation	Heat, kilocalorie/mole ( $\Delta H$ , kcal/mol)	47.5				
Wax, gm	Wax, gm	Temperature Range, °C	213-299				
Density, gm/cc		Phase	Liquid				
<b>Heat of:</b>							
Combustion, cal/gm	2285	Armor Plate Impact Test:					
Explosion, cal/gm	1280	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec					
Gas Volume, cc/gm	908	Aluminum Fineness					
Formation, cal/gm	-55	500-lb General Purpose Bomb:					
Solution, cal/mol (28-55% HNO <sub>3</sub> )	7.169*	Plate Thickness, inches					
*Assuming cyclonite unimolecular							
Specific Heat: cal/gm/°C							
$^{\circ}\text{C}$	$^{\circ}\text{C}$	1					
20	0.298	100	0.406				
40	0.331	120	0.427				
60	0.360	140	0.446				
80	0.384		1½				
			1¾				
Burning Rate: cm/sec							
Thermal Conductivity: (b) cal/sec/cm/°C							
Density, gm/cc	1.263	6.91 $\times 10^{-4}$	Bomb Drop Test:				
	1.533	6.98 $\times 10^{-4}$	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:				
Coefficient of Expansion: Linear, %/°C							
Volume, %/°C							
Hardness, Mohs' Scale:							
	2.5	Max Safe Drop, ft					
Young's Modulus:							
E', dynes/cm <sup>2</sup>		500-lb General Purpose Bomb vs Concrete:					
E, lb/inch <sup>2</sup>		Height, ft					
Density, gm/cc		Trials					
Cleavage Strength: lb/inch <sup>2</sup>		Unaffected					
Vapor Pressure: °C                  mm Mercury		Low Order					
		High Order					
1000-lb General Purpose Bomb vs Concrete:							
		Height, ft					
		Trials					
		Unaffected					
		Low Order					
		High Order					

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**Fragmentation Test:**  90 mm HE, M71 Projectile, Lot WC-91:  Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M43A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc  **Blast (Relative to TNT):**  Air: Peak Pressure Impulse Energy  Air, Confined: Impulse  Under Water: Peak Pressure Impulse Energy  Underground: Peak Pressure Impulse Energy	**Shaped Charge Effectiveness, TNT = 100:**	Glass Cones		Steel Cones																	---	--------------------------------	--------------	------	------	------	---------------	-------------------------------	----------------------------------	----------------	---------------------	--------------------------------	-------------	------	------	------	------	------		Hole Volume	Hole Depth																				Color: White																	<b>Principal Uses:</b> Detonator base charge, and ingredient for projectile and bomb fillers																			<b>Method of Loading:</b> Pressed																			<b>Loading Density: gm/cc</b> $\text{psi} \times 10^3$ <table border="1"> <thead> <tr> <th>3</th> <th>5</th> <th>10</th> <th>12</th> <th>15</th> <th>20</th> </tr> <tr> <th>1.46</th> <th>1.52</th> <th>1.60</th> <th>1.63</th> <th>1.65</th> <th>1.68</th> </tr> </thead> </table>						3	5	10	12	15	20	1.46	1.52	1.60	1.63	1.65	1.68		3	5	10	12	15	20														1.46	1.52	1.60	1.63	1.65	1.68														<b>Storage:</b> <table border="1"> <thead> <tr> <th>Method</th> <th>Wet</th> </tr> </thead> <tbody> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M (wet) Group L (dry)</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </tbody> </table>						Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M (wet) Group L (dry)	Exudation	None						Method	Wet																		Hazard Class (Quantity-Distance)	Class 9																		Compatibility Group	Group M (wet) Group L (dry)																		Exudation	None																		<b>Effect of Temperature on Rate of Detonation:</b> (k)																			<table border="1"> <thead> <tr> <th>16 hrs at, °C</th> <th>-54</th> <th>21</th> </tr> <tr> <th>Density, gm/cc</th> <th>1.61</th> <th>1.62</th> </tr> <tr> <th>Rate, m/sec</th> <th>8100</th> <th>8050</th> </tr> </thead> </table>						16 hrs at, °C	-54	21	Density, gm/cc	1.61	1.62	Rate, m/sec	8100	8050					16 hrs at, °C	-54	21																	Density, gm/cc	1.61	1.62																	Rate, m/sec	8100	8050																	<b>Effect of Temperature on Impact Sensitivity:</b>																			<table border="1"> <thead> <tr> <th>Temp. °C</th> <th>PA Impact Test 2Kg Wt, inches</th> </tr> </thead> <tbody> <tr> <td>Room</td> <td>9</td> </tr> <tr> <td>32.2</td> <td>8</td> </tr> <tr> <td>104</td> <td>5</td> </tr> </tbody> </table>						Temp. °C	PA Impact Test 2Kg Wt, inches	Room	9	32.2	8	104	5						Temp. °C	PA Impact Test 2Kg Wt, inches																		Room	9																		32.2	8																		104	5																						

Cyclonite (RDX)

Solubility of Cyclonite; gm/100 gm of the following substances: (J)

<u>Water</u>	<u>Alcohol</u>	<u>Acetone</u>	<u>Benzene</u>	<u>Toluene</u>
$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{0.005}$	$\frac{^{\circ}\text{C}}{0}$ $\frac{\text{g}}{0.040}$	$\frac{^{\circ}\text{C}}{0}$ $\frac{\text{g}}{4.4}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.05}$	$\frac{^{\circ}\text{C}}{0}$ $\frac{\text{g}}{0.015}$
$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{0.025}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.105}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{7.3}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.09}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.02}$
$\frac{^{\circ}\text{C}}{70}$ $\frac{\text{g}}{0.076}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.240}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{11.5}$	$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{0.20}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.05}$
$\frac{^{\circ}\text{C}}{90}$ $\frac{\text{g}}{0.19}$	$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{0.579}$	$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{18.}$	$\frac{^{\circ}\text{C}}{80}$ $\frac{\text{g}}{0.41}$	$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{0.13}$
$\frac{^{\circ}\text{C}}{100}$ $\frac{\text{g}}{0.28}$	$\frac{^{\circ}\text{C}}{78}$ $\frac{\text{g}}{1.195}$			$\frac{^{\circ}\text{C}}{80}$ $\frac{\text{g}}{0.30}$
				$\frac{^{\circ}\text{C}}{100}$ $\frac{\text{g}}{0.65}$
<u>Ethyl acetate</u>				
<u>Carbon tetrachloride</u>				
<u>Methanol</u>	<u>Ether</u>			<u>TNT</u>
$\frac{^{\circ}\text{C}}{25}$ $\frac{\text{g}}{2.9}$	$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{0.005}$	$\frac{^{\circ}\text{C}}{0}$ $\frac{\text{g}}{0.14}$	$\frac{^{\circ}\text{C}}{10}$ $\frac{\text{g}}{0.05}$	$\frac{^{\circ}\text{C}}{80}$ $\frac{\text{g}}{4.4}$
$\frac{^{\circ}\text{C}}{94}$ $\frac{\text{g}}{18.}$	$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{0.007}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.23}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.056}$	$\frac{^{\circ}\text{C}}{85}$ $\frac{\text{g}}{5.0}$
	$\frac{^{\circ}\text{C}}{70}$ $\frac{\text{g}}{0.009}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.47}$	$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{0.076}$	$\frac{^{\circ}\text{C}}{90}$ $\frac{\text{g}}{5.55}$
		$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{1.1}$		$\frac{^{\circ}\text{C}}{95}$ $\frac{\text{g}}{6.2}$
				$\frac{^{\circ}\text{C}}{100}$ $\frac{\text{g}}{7.0}$
				$\frac{^{\circ}\text{C}}{105}$ $\frac{\text{g}}{7.9}$
<u>Isoamyl alcohol</u>				
<u>Methyl acetate</u>				
<u>4-Ethoxyethyl acetate</u>				
<u>Chlorobenzene</u>				<u>Trichloroethylene</u>
$\frac{^{\circ}\text{C}}{0}$ $\frac{\text{g}}{0.02}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{2.9}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.15}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.33}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.20}$
$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.03}$	$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{3.3}$	$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{0.16}$	$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{0.44}$	$\frac{^{\circ}\text{C}}{30}$ $\frac{\text{g}}{0.22}$
$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.065}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{4.1}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.19}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.56}$	$\frac{^{\circ}\text{C}}{40}$ $\frac{\text{g}}{0.24}$
$\frac{^{\circ}\text{C}}{60}$ $\frac{\text{g}}{0.22}$	$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{5.6}$	$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{0.25}$	$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{0.74}$	$\frac{^{\circ}\text{C}}{50}$ $\frac{\text{g}}{0.26}$
$\frac{^{\circ}\text{C}}{80}$ $\frac{\text{g}}{0.54}$				
$\frac{^{\circ}\text{C}}{100}$ $\frac{\text{g}}{1.35}$				
<u>Tetra-chloroethane</u>				
<u>Isopropanol</u>				
<u>Isobutanol</u>				
<u>Chloroform</u>				
<u>Mesityloxide</u>				
$\frac{^{\circ}\text{C}}{35}$ $\frac{\text{g}}{0.09}$	$\frac{^{\circ}\text{C}}{35}$ $\frac{\text{g}}{0.18}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.0}$	$\frac{^{\circ}\text{C}}{20}$ $\frac{\text{g}}{0.01}$	$\frac{^{\circ}\text{C}}{27}$ $\frac{\text{g}}{3.2}$
				$\frac{^{\circ}\text{C}}{97}$ $\frac{\text{g}}{12.2}$
<u>Cyclohexanone</u>				
<u>Nitrobenzene</u>				
<u>Nitroethane</u>				
<u>Cyclopentanone</u>				
<u>Acetonitrile</u>				
$\frac{^{\circ}\text{C}}{25}$ $\frac{\text{g}}{12.7}$	$\frac{^{\circ}\text{C}}{25}$ $\frac{\text{g}}{1.5}$	$\frac{^{\circ}\text{C}}{28}$ $\frac{\text{g}}{3.6}$	$\frac{^{\circ}\text{C}}{28}$ $\frac{\text{g}}{11.5}$	$\frac{^{\circ}\text{C}}{28}$ $\frac{\text{g}}{11}$
$\frac{^{\circ}\text{C}}{97}$ $\frac{\text{g}}{25}$	$\frac{^{\circ}\text{C}}{97}$ $\frac{\text{g}}{12.4}$	$\frac{^{\circ}\text{C}}{93}$ $\frac{\text{g}}{19}$	$\frac{^{\circ}\text{C}}{90}$ $\frac{\text{g}}{37}$	$\frac{^{\circ}\text{C}}{82}$ $\frac{\text{g}}{33}$
<u>Methyl ethyl ketone</u>				
$\frac{^{\circ}\text{C}}{28}$		$\frac{\text{g}}{5.6}$		
	$\frac{^{\circ}\text{C}}{95}$	$\frac{\text{g}}{14}$		

Cyclonite (RDX)

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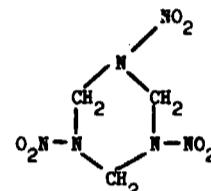
Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

<u>Solvent</u>	<u>Boiling Point, °C</u>	<u>Grade or Source</u>	<u>Solubility g/100 gm</u>		<u>Crystalline Form</u>
			<u>26°C</u>	<u>Heated</u>	
Acetone	56	CP	8.2	16.5 at 60°C	hexagonal-thick
Cyclohexanone	155.6	CP	13.0	24.0 at 93°C	cubic (massive form)
Nitromethane	100.8		1.5	12.4 at 97°C	plates
Acetonitrile	81.6	Macet Chem. Co.	11.3	33.4 at 93°C	plates
1-Nitropropane	126.5	EK Pract	1.4	10.6 at 93°C	short needles
2-Nitropropane	120	EK Pract	2.3	11.6 at 93°C	short needles
2,4-Pentanedione	140.5	Carbide & Carbon	2.9	18.3 at 93°C	flat prisms
Methylisobutylketone	115.8		2.4	9.6 at 93°C	long prisms
n-Propylacetate	101.6	EK Red Label	1.5	6.0 at 93°C	long prisms, some cubic
n-Butylformate	105.6	EK Red Label	1.4	4.6 at 93°C	long prisms
Ethyl acetate	77.1	Baker's P	2.0	6.1 at boil.	hexagonal plates
n-Propylpropionate	121	EK Red Label	0.8	1.6 at 93°C	short prisms, some cubic
Butylacetate	126.5	EK Technical	1.1	4.0 at 93°C	long prisms
Methylethylketone	79.6		5.6	13.9 at boil.	coarse plates
Nitroethane	114.2	EK Red Label	3.6	19.5 at 93°C	plates
Isopropylacetate	88-90	CP	1.1	3.2 at boil.	long prisms
Mesityloxide	128	EK Red Label	4.8	14.5 at 93°C	plates
n-Amylacetate	146	CP	1.0	2.1 at 93°C	prisms
Dimethylcarbonate	88-91	EK Red Label	1.4	6.6 at boil.	plates
Diethylcarbonate	125-126.5	EK Red Label	0.7	3.2 at 93°C	prisms
Isomylacetate	132	CP	1.2	3.6 at 93°C	prisms
Ethylpropionate	98-100	EK Red Label	3.0	10.7 at 93°C	fairly thick hex plates
Methyl-n-butyrate	101.5-103.5	EK Red Label	1.2	4.9 at 93°C	needles
Cyclopentanone	130.6	EK Red Label	11.5	39.0 at 93.5°C	hexagonal plates
Acrylonitrile	77.3	Cyanimid Co.	4.0	16.4 at boil.	flat plates
Methylcellulosolveacetate	144.5	Carbide & Carbon	1.6	8.8 at 93°C	massive hexagons and prisms

\* EK, Eastman Kodak; Pract, practical.

Cyclonite (RDX)Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)



Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable  $\beta$ -HMX. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-8% HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1,402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling should be continued for one-half hour.

References:<sup>14</sup>

- (a) I. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Macum, Z. ges. Schieß-Sprengstoffw., pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NWORD Report No. 87-46, 26 July 1946.

<sup>14</sup>See footnote 1, page 10.

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(e) Armament Research Department (Woolwich), Solubility of RDX in Nitric Acid (ARD Expl Rpt 322/43 September 1943).

(f) Report AC-2587.

(g) International Critical Tables  
Land. Bornst.

B. T. Fedoroff et al, A Manual for Explosives Laboratories, Lefax Society Inc, Philadelphia, 1943-6.

(h) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2661, First Report, August 1942.

(i) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(j) International Critical Tables.

(k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

(l) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

0	1	2	3	4	5	6	7	8	9
1170	1211	582	863	1184	65	1236	857	1438	709
1290	1241	1342	1193	1414	1175	1316	1207	1458	1379
1360	1311	1352	1293	1454	1185	1416	1427	1498	1429
1450	1421	1372	1433	1614	1435	1446	1437	1578	1449
1760	1481	1402	1483	1634	1445	1466	1517	1838	1469
1980	1561	1452	1503	2024	1715	1476	1617	1958	1709
2100	1611	1492	1693	2154	1855	1516	1687	1958	1909
	1651	1532	1713	2204	1885	1556	1737	2008	2059
	1741	2062	1793		1915	1756	1747	2028	2179
	1751	2112	1923		1935	1766	1787	2178	
	1761				2095	1796	1797	2198	
	2131				2125	1836	1957		
	2151				2205	1936	2147		
						1956	2227		
						2016			
						2056			
						2176			

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Cyclotol, 75/25

<b>Composition:</b> % RDX            75 TNT            25  <b>C/H Ratio</b>	<b>Molecular Weight:</b>	224
	<b>Oxygen Balance:</b>	
	CO, %	-35
	CO %	-6
	<b>Density: gm/cc</b>	<b>Cast</b> 1.71
	<b>Melting Point: °C</b>	
	<b>Freezing Point: °C</b>	
	<b>Boiling Point: °C</b>	
	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C	
<b>Rifle Bullet Impact Test:</b> Trials  Explosions            % Partials            Shocks      40 Burned            0 Unaffected            30	100°C	0.23
	120°C	0.41
	135°C	-
	150°C	-
	<b>200 Gram Bomb Sand Test:</b> Sand, gm	
	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm	
	Mercury Fulminate	
	Lead Azide	
	Tetryl	
	<b>Ballistic Mortar, % TNT:</b>	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Tread Test, % TNT:</b>	
	<b>Plate Dent Test:</b> Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
	<b>Detonation Rate:</b>	
	Confinement	None      None
	Condition	Cast      Cast
	Charge Diameter, in.	1.0      1.0
<b>Flammability Index:</b>	Density, gm/cc	1.70      1.71
	Rate, meters/second	8035      7938
<b>Hygroscopicity:</b> %		
<b>Volatility:</b>		

Cyclotol, 75/25

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<b>Booster Sensitivity Test:</b>	<b>Decomposition Equation:</b>
Condition	Oxygen, atoms/sec (Z/sec)
Tetryl, gm	Heat, kilocalorie/mole (ΔH, kcal/mol)
Wax, in. for 50% Detonation	Temperature Range, °C
Wax, gm	Phase
Density, gm/cc	
<b>Heat of:</b>	<b>Armor Plate Impact Test:</b>
Combustion, cal/gm	2625*
Explosion, cal/gm	1225*
Gas Volume, cc/gm	862
Formation, cal/gm	
Fusion, cal/gm	(b) 5.0
<b>*Calculated from composition of mixture.</b>	
<b>Specific Heat: cal/gm/°C</b>	<b>60 mm Mortar Projectile:</b>
<b>(b)</b>	50% Inert, Velocity, ft/sec
<b>  °C</b>	Aluminum Fineness
-75 0.220	75 0.352
0 0.225	85 0.325
25 0.254	90 0.332
50 0.296	100 0.351
<b>Burning Rate:</b>	<b>500-lb General Purpose Bombs:</b>
cm/sec	Plate Thickness, inches
	1
	1 1/4
	1 1/2
	1 3/4
<b>Thermal Conductivity:</b>	<b>Bomb Drop Test:</b>
cal/sec/cm/°C	<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>
	Max Safe Drop, ft
<b>Coefficient of Expansion:</b>	<b>500-lb General Purpose Bomb vs Concrete:</b>
Linear, %/°C	Height, ft
	Trials
<b>Volume, %/°C</b>	Unaffected
<b>Hardness, Mohs' Scale:</b>	Low Order
<b>Young's Modulus:</b>	High Order
E', dynes/cm <sup>2</sup>	<b>1000-lb General Purpose Bomb vs Concrete:</b>
E, lb/inch <sup>2</sup>	Height, ft
Density, gm/cc	Trials
<b>Compressive Strength: lb/inch<sup>2</sup></b>	Unaffected
<b>Vapor Pressure:</b>	Low Order
°C	High Order
	mm Mercury

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Cyclotol, 75/25

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-01:</b>		Gloss Cones	Steel Cones
Density, gm/cc	1.72	Hole Volume	
Charge Wt, lb	2.22	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Yellow-buff	
For Subject HE	1514		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Shaped charge bomb especially fragmentation; HE projectiles; grenades	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Cast	
For TNT			
For Subject HE		<b>Loading Density: gm/cc</b>	
<b>Fragment Velocity: ft/sec</b>		1.71	
At 9 ft			
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		<b>Method</b>	
(d)		Dry	
Air:		<b>Hazard Class (Quantity-Distance):</b>	
Peak Pressure	111	Class 9	
Impulse	126		
Energy	--	<b>Compatibility Group:</b>	
<b>Air, Confined:</b>		Group I	
Impulse		<b>Erosion:</b>	
<b>Under Water:</b>		<b>Preparation:</b> See Composition B	
Peak Pressure		<b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.	
Impulse		<b>Black Modulus at Room Temperature (25°-30°C):</b>	
Energy		Dynes/cm² x 10⁻¹⁰	3.09
<b>Underground:</b>		Density, gm/cc	1.74
Peak Pressure		<b>Absolute Viscosity, poises:*</b>	
Impulse		Temp, 85°C	210**
Energy		90°C	--
<b>Efflux Viscosity, Saybolt Seconds:</b>		<b>Efflux Viscosity, Saybolt Seconds:</b>	
		Temp, 85°C	9-14
* Compositions using Spec Grade Type A, Class A RDX.			
** Composition prepared using RDX of optimum particle size.			

Cyclotol, 70/30

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<b>Composition:</b> %		<b>Molecular Weight:</b>	224
RDX	70	Oxygen Balance: CO <sub>2</sub> %	-37
TNT	30	CO %	-8
		<b>Density:</b> gm/cc      Cast	1.71
		<b>Melting Point:</b> °C	
		<b>Freezing Point:</b> °C	
		<b>Boiling Point:</b> °C	
		<b>Refractive Index,</b> n <sub>D<sup>20</sup></sub> n <sub>D<sup>25</sup></sub> n <sub>D<sup>30</sup></sub>	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	60	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Sample Wt 20 mg		90°C	
Picatinny Arsenal Apparatus, in.	14	100°C	
Sample Wt, mg	20	120°C	0.86
		135°C	
		150°C	
<b>Friction Pendulum Test:</b>		<b>200 Gram Bomb Sand Test:</b>	
Steel Shoe	Unaffected	Sand, gm	56.6
Fiber Shoe	Unaffected		
<b>Rifle Bullet Impact Test:</b>	Trials		
	%		
Explosions	30	<b>Sensitivity to Initiation:</b>	
Partials	30	Minimum Detonating Charge, gm	
Burned	0	Mercury Fulminate	0.21*
Unaffected	40	Lead Azide	0.20*
		Tetryl	
<b>Explosion Temperature:</b>	°C	*Alternative initiating charges.	
Seconds, 0.1 (no cap used)	-		
1	-	<b>Ballistic Merit, % TNT:</b> (a)	135
5 Decomposes	265		
10		<b>Trend Test, % TNT:</b>	
15			
20		<b>Plate Dent Test:</b> (b)	
		Method	B
<b>75°C International Heat Test:</b>		Condition	Cast
% Loss in 48 Hrs		Confined	No
		Density, gm/cc	1.725
<b>100°C Heat Test:</b>		Brisance, % TNT	136
% Loss, 1st 48 Hrs	0.07		
% Loss, 2nd 48 Hrs	0.08		
Explosion in 100 Hrs	None		
<b>Flammability Index:</b>			
<b>Hygroscopicity:</b> %	Nil	<b>Detonation Rate:</b>	
<b>Volatility:</b>	Nil	Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.73
		Rate, meters/second	8060

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M3: Projectile, Lot WC-91:		Gloss Cones	Steel Cones (e)
Density, gm/cc	1.71	Hole Volume	
Charge Wt, lb	2.213	Hole Depth	130
<b>Total No. of Fragments:</b>			
For TNT	703	<b>Color:</b>	
For Subject HE	1165	Yellow-buff	
<b>3 inch HE, M42A1 Projectile, Lot KC-8:</b>			
Density, gm/cc	1.72	<b>Principal Uses:</b> Shaped charge bombs; especially fragmentation HE projectiles, grenades	
Charge Wt, lb	0.923		
<b>Total No. of Fragments:</b>			
For TNT	514	<b>Method of Loading:</b>	
For Subject HE	828	Cast	
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		1.71	
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		Method	
Air:	(d)	Dry	
Peak Pressure	110	<b>Hazard Class (Quantity-Distance):</b>	
Impulse	120	Class 9	
Energy	--	<b>Compatibility Group:</b>	
<b>Air, Confined:</b>		Group I	
Impulse		<b>Exudation:</b>	
<b>Under Water:</b>			
Peak Pressure		<b>Preparation:</b> See Composition B	
Impulse		<b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.	
Energy			
<b>Underground:</b>		<b>Absolute Viscosity, poises:</b> *	
Peak Pressure		Temp, 85°C	--
Impulse		90°C	53.2
Energy		<b>Efflux Viscosity, Saybolt Seconds:</b>	
		Temp, 85°C	5
		Heat of:	--
		Combustion, cal/gm	2685
		Explosion, cal/gm	1213
		Gas Volume, cc/gm	854
* Composition using Spec Grade Type A, Class A RDX.			
** Calculated from position of mixture.			

Cyclotol, 65/35

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Composition: % RDX                    55 TNT                    35	Molecular Weight:	224
	Oxygen Balance: CO <sub>2</sub> %                -40 CO %                    - 9	
	Density: gm/cc      Cast	1.71
	Melting Point: °C	
C/H Ratio	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mine Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt. mg	Boiling Point: °C	
Friction Pendulum Test: Steel Shoe              Unaffected Fiber Shoe              Unaffected	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Rifle Bullet Impact Test:      Trials Explosions              % Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Explosion Temperature:      °C Seconds, 0.1 (no cap used) 1                          270 5 Decomposes            270 10 15 20	200 Gram Bomb Sand Test: Sand, gm                55.4	
75°C International Heat Test: % Loss in 48 Hrs	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Ballistic Mortar, % TNT: (s)      134	
Flammability Index:	Tread Test, % TNT:	
Hygrosopicity: %            Nil	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Volatility:                Nil	Detonation Rate: Confinement              None Condition                Cast Charge Diameter, in.    1.0 Density, gm/cc           1.72 Rate, meters/second     7.97	

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Cyclotol, 65/35

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>				
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones	(e)		
Density, gm/cc	1.71	Hole Volume				
Charge Wt, lb	2.253	Hole Depth	130			
<b>Total No. of Fragments:</b>		<b>Color:</b>				
For TNT	703	Yellow-buff				
For Subject HE	1153					
3 inch HE, M43A1 Projectile, Lot KC-5:		<b>Principal Uses:</b> Shaped charge bombs; especially fragmentation HE projectiles, grenades				
Density, gm/cc	1.71					
Charge Wt, lb	0.922					
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>				
For TNT	514	Cast				
For Subject HE	769					
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>				
At 9 ft		1.71				
At 25½ ft						
Density, gm/cc						
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>				
Air:		Method	Dry			
Peak Pressure		Hazard Class (Quantity-Distance)	Class 9			
Impulse		Compatibility Group	Group I			
Energy		Exudation				
Air, Confined:		<b>Preparation:</b> See Composition B				
Impulse		<b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.				
Under Water:						
Peak Pressure		<b>Eutectic Temperature, °C:</b>				
Impulse		gm RDX/100 gm TNT	79			
Energy		79°C	4.16			
Underground:		95°C	5.85			
Peak Pressure		<b>Absolute Viscosity, poises:*</b>				
Impulse		Temp, 85°C	30.2			
Energy		90°C	26.0			
Heat of:	*					
Combustion, cal/gm	2755	<b>* Composition using Spec Grade Type A, Class A RDX.</b>				
Explosion, cal/gm	1205					
Gas Volume, cc/gm	845					
* Calculated from composition of mixture.						

Cyclotol, 60/40

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Composition:		Molecular Weight:	224
%			
RDX	60	Oxygen Balance:	
TNT	40	CO <sub>2</sub> %	-43
		CO %	10
C/H Ratio		Density: gm/cc	Cast 1.68
Impact Sensitivity, 2 Kg Wt:		Melting Point: °C	
Bureau of Mines Apparatus, cm	75	Freezing Point: °C	
Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.	14	Refractive Index, n <sub>d20</sub> <sup>20</sup>	
Sample Wt, mg	19	n <sub>d20</sub> <sup>20</sup>	
		n <sub>d20</sub> <sup>20</sup>	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
20% Bullet Impact Test: Trials		100°C	
	%	120°C	0.29
Explosions	5	135°C	
Particals	55	150°C	
Burned	25	200 Gram Bomb Sand Test:	
Unaffected	15	Sand, gm	54.6
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.22*
5 Decomposes	280	Lead Azide	0.20*
10		Tetryl	
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT: (a)	1.33
75°C International Heat Test:		Trexel Test, % TNT:	
% Loss in 48 Hrs		Plate Dot Test: (b)	
100°C Heat Test:		Method	B
% Loss, 1st 48 Hrs		Condition	Cast
% Loss, 2nd 48 Hrs		Confined	No
Explosion in 100 Hrs		Density, gm/cc	1.72
Flammability Index:		Brisance, % TNT	132
Hygroscopicity: %		Detonation Rate:	
	N11	Confinement	None
Velocity:		Condition	Cast
	N11	Charge Diameter, in.	1.0
		Density, gm/cc	1.72
		Rate, meters/second	7900

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>				
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>						
Density, gm/cc	1.65	Glass Cones	178	Steel Cones (e)		
Charge Wt, lb	2.187	Hole Volume	162			
<b>Total No. of Fragments:</b>		Hole Depth				
For TNT	703	125	148			
For Subject HE	998					
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>						
Density, gm/cc	1.67					
Charge Wt, lb	0.882					
<b>Total No. of Fragments:</b>						
For TNT	514					
For Subject HE	701					
<b>Fragment Velocity: ft/sec (c)</b>		<b>Method of Loading:</b>				
At 9 ft	2965	Cast				
At 25½ ft	2800					
Density, gm/cc	--	<b>Leading Density: gm/cc</b>				
<b>Blast (Relative to TNT): (d)</b>		1.68				
<b>Air:</b>		<b>Storage:</b>				
Peak Pressure	104	Method	Dry			
Impulse	116	Hazard Class (Quantity-Distance)	Class 9			
Energy	--	Compatibility Group	Group I			
<b>Air, Confined:</b>		Exudation				
Impulse						
<b>Under Water:</b>		<b>Preparation:</b> See Composition B				
Peak Pressure		<b>Origin:</b> Developed by the British between				
Impulse		World Wars I and II and standardized in				
Energy		the United States early in World War II.				
<b>Underground:</b>		<b>Bulk Modulus at Room Temperature (25°-30°C):</b>				
Peak Pressure		Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>	4.14			
Impulse		Density, gm/cc	1.72			
Energy						
<b>Heat of:</b>		<b>Absolute Viscosity, poises:*</b>				
Combustion, cal/gm	2820	Temp, 85°C	12.3			
Explosion, cal/gm	1195	90°C	--			
Gas Volume, cc/gm	845					
<b>Compressive Strength: lb/inch<sup>2</sup></b>		<b>* Compositions using Spec Grade Type A, Class A RDX.</b>				
1.70 cm <sup>2</sup> /cc	2200-3000					

\* Calculated from composition of mixture.

References:<sup>15</sup>

- (a) L. C. Smith and E. G. Kyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5628, 2 January 1946.
- (d) V. Philipchuk, Free Air Blast Evaluation of RDX-TNT-Al, RDX-TNT, and TNT-Metal Systems, National Northern Summary Report, NN-P-34, April 1956.
- (e) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Section III, Variation of Cavity Effect with Composition, NIDC Contract W-672-ORD-5723.
- (f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

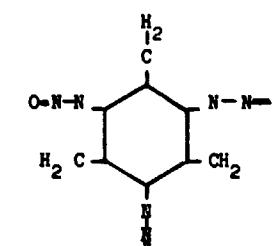
(g) Also see the following Picatinny Arsenal Technical Reports on Cyclotols:

0	1	2	3	4	5	6	7	8	9
1290	1651	1482	1483	1824	1435	1476	1427	1398	1469
1530	1741		1793	1834	1585	1756	1507	1488	1509
		19 <sup>o</sup> 3	1944			1796	1747	1838	1709
				2004		1876			

- (h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

<sup>15</sup>See footnote 1, page 10.

Cyclotrimethylene Trinitrosoamine

<b>Composition:</b> %		<b>Molecular Weight:</b> ( $C_3H_6N_6O_3$ )	174
C 20.6		Oxygen Balance: CO <sub>2</sub> %	-55
H 3.5		CO %	-28
N 48.3		<b>Density:</b> gm/cc	
O 27.6		<b>Melting Point:</b> °C	105 to 107
C/H Ratio 0.12		<b>Frosting Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg		<b>Boiling Point:</b> °C	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	15 to 22 17 to 20	<b>Refractive Index,</b> $n_D^{20}$ $n_D^{25}$ $n_D^{28}$	
<b>Friction Pendulum Test:</b> Steel Shoe                          Unaffected Fiber Shoe                          Unaffected		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C                                0.20 100°C                              9.19    3.71*	(c)
<b>Rifle Bullet Impact Test:</b> Trials Explosions                         % Partials Burned Unaffected		*Average value of 5 gm sample twice recrystallized from isoamyl alcohol.	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1                                    220 5 10 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate                0.200** Lead Azide                        0.100** Tetryl                              **Alternative initiating charges.	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b> 130	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs                8.79 % Loss, 2nd 48 Hrs                2.98 Explosion in 100 Hrs            None		<b>Trend Test, % TNT:</b>	
<b>Flammability Index:</b>		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brionce, % TNT	
<b>Hygroscopicity:</b> % 30°C, 90% RH    0.02			
<b>Volatility:</b>		<b>Detonation Rate:</b> Confinement                        (b) None Condition                           Cast Charge Diameter, in.            1.2 Density, gm/cc                    1.42 Rate, meters/second              7000 to 7300	

Cyclotrimethylene Trinitrosoamine

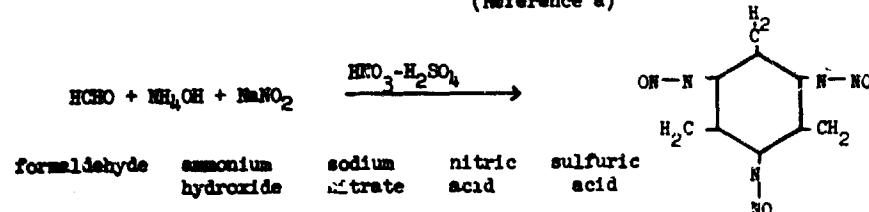
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<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  <b>Color:</b> Yellow  <b>Principal Uses:</b> Ingredient of projectile filler  <b>Mixed of Loading:</b> Pressed or cast with added melting point depressants  <b>Loading Density:</b> gm/cc      See below  <b>Storage:</b>  <b>Method</b> Dry  <b>Hazard Class (Quantity-Distance)</b> Class 9  <b>Compatibility Group</b> Group M  <b>Exudation</b> None															
<b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<b>Density at Various Pressures:</b> (lb/inch) <sup>2</sup> gm/cc <table> <tbody> <tr> <td>2,420</td> <td>1.1C</td> </tr> <tr> <td>4,830</td> <td>1.23</td> </tr> <tr> <td>9,650</td> <td>1.37</td> </tr> <tr> <td>14,500</td> <td>1.44</td> </tr> <tr> <td>24,200</td> <td>1.53</td> </tr> <tr> <td>33,800</td> <td>1.57</td> </tr> <tr> <td>42,500</td> <td>1.59</td> </tr> </tbody> </table> <b>Heat of:</b> Combustion, cal/gm      3158 Explosion, cal/gm      876 Formation, cal/gm      -914		2,420	1.1C	4,830	1.23	9,650	1.37	14,500	1.44	24,200	1.53	33,800	1.57	42,500	1.59
2,420	1.1C																
4,830	1.23																
9,650	1.37																
14,500	1.44																
24,200	1.53																
33,800	1.57																
42,500	1.59																

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Cyclotrimethylene Trinitrosamine

Preparation of Hexahydro-1,3,5-Trinitroso-a-triazine Cyclotrimethylene Trinitrosamine:  
(Reference a)



An ammoniacal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35°C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-ammonia solution and totally dissolved by stirring. This solution is chilled to below 0°C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9°C, there is added the cold amine-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitrosamine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and air-dried on filter paper. The dry crude product melts at 106° to 107°C. Recrystallization from isooxy alcohol gives a pure compound melting at 105° to 107°C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Dušan and Scherff (Ann 268 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HBC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

Cyclotrimethylene Trinitrosoamine

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High Temperature Decomposition, 0.02 gm in 10 ml Test Tube: (b)

Immersed 10 minutes in bath heated at 5°/minute	
	Temp. °C
(1) Melting begins	105
Decomposition begins	150
Nitrous gas	160
Entire decomposition	170
(2) Some bubbles	110
Very slow decomposition	150
Decomposes in 2 minutes	200
Decomposes in 40 seconds	250
Immediate decomposition	300

Long Term Stability: (b)

Cyclotrimethylene Trinitrosoamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

1. Explosive showed no color change.
2. Melting point decreased from 104.5° to 104°C.
3. Coefficient of "Utilisation Practique" decreased from 125.5 to 123.5.
4. An Iodel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosoamine and TNT: (b)

Cyclotrimethylene Trinitrosoamine, %	Melting Point, °C
10	74
20	68
30	62
40	55
42	55 (Eutectic)
50	61
60	69
70	77
95	95

Eutectic Composition With TNT: (b)Rate of Detonation, meters/second

42% Cyclotrimethylene Trinitrosoamine

7,000

58% TNT

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Cyclotrimethylene Trinitrosoamine

Reaction of Cyclotrimethylene Trinitrosoamine With Other Materials: (b)

1. Iron powder	Slight reaction
2. Copper powder	Slight reaction
3. Aluminum powder	Slight reaction
4. 2 parts picric acid + 1 part R-Salt	a. Violent decomposition after 2 hours at 10°C b. Violent decomposition after 10 to 15 minutes at 100°C
5. 2 parts nitroglycerin + 1 part R-Salt	No evidence of decomposition after 5 days at 90°C

Detonation Rate: (b)

Conf'g'ement	Paper cartridge
Condition	pressed
Charge Diameter, in.	1.18
Rate, meters/second	Density, gm/cc
5180	0.85
5760	1.00
6600	1.20
7330	1.40
7600	1.50
7800	1.57

References:<sup>16</sup>

- (a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DA-19-020-501-ORD(P)-33.
- (b) Louis Médard and Maurice Dutour, "Etude Des Propriétés De La Cyclotriméthylène Trinitrosoamine," Méta poudr., 37, 1924 (1954).
- (c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.
- (d) Also see the following Picatinny Arsenal Technical Reports on Cyclotrimethylene Trinitrosoamine: 1174, 2179.

<sup>16</sup>See footnote 1, page 10.

DBX (Depth Bomb Explosive)

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<b>Composition:</b> %		<b>Molecular Weight:</b>	83
Ammonium Nitrate	21	Oxygen Balance: CO <sub>2</sub> %	-46
RDX	21	CO %	-26
TNT	40	<b>Density:</b> gm/cc	Cast 1.68
Aluminum	18	<b>Melting Point:</b> °C	
C/H Ratio		<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	35	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		Refractive Index, n <sub>D</sub> <sup>20</sup>	
Picatinny Arsenal Apparatus, in.	13	n <sub>D</sub> <sup>20</sup>	
Sample Wt, mg	14	n <sub>D</sub> <sup>20</sup>	
<b>Friction Pendulum Test:</b> Steel Shoe		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Fiber Shoe		90°C	
<b>Rifle Bullet Impact Test:</b> Trials	%	100°C	
Explosions		120°C	6.15
Partials		135°C	
Burned		150°C	
Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm	58.5
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm:	
1		Mercury Fulminate	
5 Ignites	400	Lead Azide	0.20
10		Tetryl	0.10
15			
20			
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b> (a) 146	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		<b>Troux Test, % TNT:</b>	
% Loss, 2nd 48 Hrs		<b>Plate Dent Test:</b> (b)	
Explosion in 100 Hrs		Method	B
		Condition	Cast
		Confined	No
		Density, gm/cc	1.76
		Brisance, % TNT	102
<b>Flammability Index:</b>		<b>Detonation Rate:</b> (c)	
<b>Hygrosopicity:</b> %		Confinement	None
<b>Volatility:</b>		Condition	Cast
		Charge Diameter, in.	1.6
		Density, gm/cc	1.65
		Rate, meters/second	6600

<b>Booster Sensitivity Test:</b>	(e)	<b>Decomposition Equation:</b>
Condition	Cast	Oxygen, atoms/sec (Z/sec)
Tetryl, gm	100	Heat, kilocalorie/mole (ΔH, kcal/mol)
Wax, in. for 50% Detonation	1.35	Temperature Range, °C
Wax, gm		Phase
Density, gm/cc	1.76	
 <b>Heat of:</b>	(d)	 <b>Armor Plate Impact Test:</b>
Combustion, cal/gm		60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec
Explosion, cal/gm	1700	Aluminum Fineness
Gas Volume, cc/gm		
Formation, cal/gm		 <b>500-lb General Purpose Bombs:</b>
Fusion, cal/gm		Plate Thickness, inches
 <b>Specific Heat:</b> cal/gm/°C	(d)	1
-5°C, density 1.75 gm/cc	0.25	1 1/4
		1 1/2
		1 3/4
 <b>Burning Rate:</b> cm/sec		 <b>Bomb Drop Test:</b>
 <b>Thermal Conductivity:</b> cal/sec/cm/°C	13.2 × 10 <sup>-4</sup>	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Density 1.75 gm/cc		Max Safe Drop, ft
 <b>Coefficient of Expansion:</b> Linear, %/°C -73°-75°C	4.5 × 10 <sup>-5</sup>	 <b>500-lb General Purpose Bomb vs Concrete:</b>
Volume, %/°C		Height, ft
 <b>Hardness, Mohs' Scale:</b>		Trials
 <b>Young's Modulus:</b>	(a)	Unaffected
E', dynes/cm <sup>2</sup>	10.4 × 10 <sup>10</sup>	Low Order
E, lb/inch <sup>2</sup>	1.51 × 10 <sup>6</sup>	High Order
Density, gm/cc	1.72	 <b>1000-lb General Purpose Bomb vs Concrete:</b>
 <b>Compressive Strength:</b> lb/inch <sup>2</sup> (d) 3210-3380		Height, ft
Density 1.78 gm/cc		Trials
 <b>Vapor Pressure:</b>		Unaffected
°C	mm Mercury	Low Order
		High Order

DBX (Depth Bomb Explosive)

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones      Steel Cones	
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Gray	
For Subject HE		<b>Principal Use:</b>	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		Depth charge	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Cast	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		1.61-1.69	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
(d)		Method	
Air:		Dry	
Peak Pressure			
Impulse		<b>Hazard Class (Quantity-Distance):</b>	
Energy		Class 1	
		<b>Compatibility Group:</b>	
		Group I	
<b>Air, Confined:</b>		<b>Exudation:</b>	
Impulse			
<b>Under Water:</b>		<b>Preparation:</b>	
Peak Pressure		DBX can be manufactured by slowly adding water-wet RDX to molten TNT melted in a steam-jacketed kettle equipped with a stirrer. When all the water has evaporated, ammonium nitrate is added and with heating and stirring continued, grained aluminum is added. The mixture is cooled with stirring continued to maintain uniformity and when suitable for pouring the mixture is cast. DBX can also be made by adding 21% ammonium nitrate and 18% aluminum to 42% cyclotol or Composition B of 50/50 RDX/TNT content plus 1% of TNT previously melted at about 100°C.	
--			
Impulse			
Energy			
<b>Underground:</b>			
Peak Pressure			
Impulse			
Energy			

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DBX (Depth Bomb Explosive)

Origin:

DBX was developed and used by the United States and Great Britain during World War II.

References:<sup>17</sup>

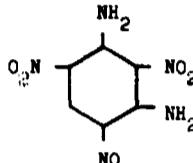
- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- (d) M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (f) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

(g) Also see the following Picatinny Arsenal Technical Reports on DBX: 1585 and 1635.

<sup>17</sup>See footnote 1, page 10.

1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

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<b>Composition:</b> % C 29.6 H 2.1 N 28.8 O 39.5 C/H Ratio 0.380	<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>5</sub> N <sub>2</sub> O <sub>6</sub> ) 243
	<b>Oxygen Balance:</b> CO <sub>2</sub> % CO %
	<b>Density:</b> gm/cc <b>Crystal</b> 1.83
	<b>Melting Point:</b> °C (a) 290
	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg      18 Picatinny Arsenal Apparatus, in. Sample Wt, mg      9	<b>Boiling Point:</b> °C
	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 46.6
<b>Explosion Temperature:</b> °C Seconds, C.I. (no cap used) 1 5 10 15 20	<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b> 100
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.4 Explosion in 100 Hrs None	<b>Treux Test, % TNT:</b> <b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Flammability Index:</b>	<b>Detonation Rate:</b> Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.55 Rate, meters/second 7500
<b>Hygroscopicity:</b> %	
<b>Volatility:</b>	

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1,3-Diamino-2,4,6-Tri-nitrobenzene (DATNB)

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 Inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p> <p><b>Blast (Relative to TNT):</b></p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<b>Shaped Charge Effectiveness, TNT = 100:</b>	
	Glass Cones	Steel Cones
	Hole Volume	
	Hole Depth	
	Color:	Yellow
	<b>Principal Uses:</b>	
	Method of Loading:	Pressed
	Loading Density: gm/cc At 50,000 psi	1.65
	<b>Storage:</b>	
	Method	Dry
<b>Hazard Class (Quantity-Distance)</b>		
<b>Compatibility Group</b>		
<b>Exudation</b>		
<b>Cook-Off Temperature: °C</b>		
Time, minutes		
<b>Heat of:</b>		
Explosion, cal/gm		
2876		

1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (V) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to 170°C (literature melting point 173°C).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130° to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (77%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATNB, also called 2,4,6-trinitro-1,3-diamino-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber 17, 260) and also by Barr in 1888 (Ber 21, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATNB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene hydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH<sub>3</sub> and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13, 60).

Körner and Contardi prepared DATNB by the reaction of either 2,4-dichloro-1,3,5-trinitrobenzene or 2,4-dibromo-1,3,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetrinitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schepers (Akad Amsterdam Versl 22, 297).

C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennepe reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminoanisole or 2,4,6-trinitro-3-aminophenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 39, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis (-nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim 46, 649) (Beil E 17, E II 33).

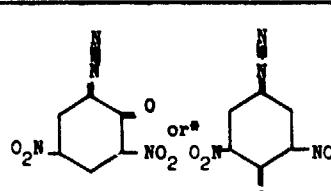
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1,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

A recent report describes the preparation of DATNB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with  $H_2SO_4$ - $HNO_3$  acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to diamino trinitrobenzene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATNB was obtained by this method, which can easily be carried out on a commercial scale.

Diazodinitrophenol

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<b>Composition:</b> % C 34.3 H 0.9 N 26.7 O 38.1 C/H Ratio 1.056		<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>2</sub> N <sub>4</sub> O <sub>5</sub> ) 210
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4; (1 lb wt) 7 Sample Wt, mg 15		<b>Oxygen Balance:</b> CO <sub>2</sub> % -61 CO % -15
		<b>Density:</b> gm/cc Crystal 1.63
		<b>Melting Point:</b> °C 157
		<b>Freezing Point:</b> °C
		<b>Boiling Point:</b> °C
<b>Friction Pendulum Test:</b> Steel Shoe Detonates Fiber Shoe Detonates		<b>Refractive Index:</b> n <sub>D<sup>20</sup></sub> n <sub>D<sup>25</sup></sub> n <sub>D<sup>30</sup></sub>
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 7.6 120°C 135°C 150°C
		<b>200 Gram Bomb Sand Test:</b> Sand, gm Black powder fuse 47.5 45.6
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 200 5 195 10 180 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10
		<b>Ballistic Mortar, % TNT:</b> (a) 97
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Treuzzi Test, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 2.10 % Loss, 2nd 48 Hrs 2.20 Explosion in 100 Hrs None		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Flammability Index:</b>		<b>Detonation Rate:</b> Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 0.9 1.5 1.6 Rate, meters/second 4400 6600 6900
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.04		
<b>Volatility:</b> 50°C, 30 months Unaffected		

\*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).

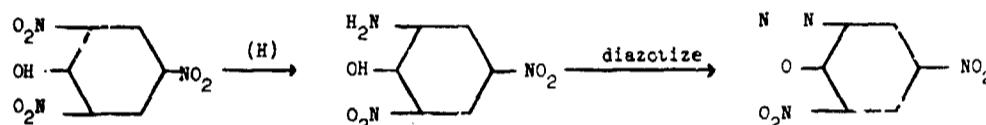
<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Yellow needles	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b>	
Density, gm/cc		Percussion caps	
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Pressed	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		Apparent	
At 25½ ft		At 3000 psi	
Density, gm/cc		0.27	
		1.14	
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		Method	Under water
Peak Pressure			
Impulse			
Energy			
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance)</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group</b>	
Peak Pressure			
Impulse			
Energy		<b>Exudation</b>	
<b>Underground:</b>		None	
Peak Pressure			
Impulse			
Energy			
<b>Solubility:</b>			
Soluble in nitroglycerin, nitrobenzene, aniline, pyridine, concentrated hydrochloric acid, and in most common organic solvents.			
<b>Heat of:</b>			
Combustion, cal/gm		3243	
Explosion, cal/gm		820	
Gas Volume, cc/gm		865	
<b>Sensitivity to Electrostatic Discharge, Joules:</b>		(c) 0.012	

Diazodinitro Phenol

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Solubility: gm/100 ml of the following substances: (c)Solubility at 50°C

<u>Solvent</u>	<u>%</u>
Etoyl acetate	2.45
Methanol	1.25
Ethanol	2.43
Ethylenedichloride	0.79
Carbon tetrachloride	trace
Chloroform	0.11
Benzene	0.23
Toluene	0.15
Petroleum ether	Insoluble (at 20°C)
Ethyl ether	0.08 (30°C)
Carbon disulfide	trace (30°C)

Preparation: (Chemistry of Powder and Explosives, Davis)

Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0°C. 3.6 gm sodium nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Gries in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 603 (1933). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed by adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

References: 18

- (a) Philip C. Keenan and Dorothy Pines, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (b) F. W. Lewin, D. H. Kusler and T. C. Gibson, Sensitivity of Explosives to Initiation by

<sup>18</sup>See footnote 1, page 10.

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Diazodinitrophenol

Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinitrophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

0	2	4	6	7	8	9
150	1352	34	355	827	318	2179
610		214			1838	
2120						

Diethylene Glycol Dinitrate (DEGN) Liquid

AMCP 706 177

<b>Composition:</b> % C 24.5 $\begin{array}{c} \text{H}_2\text{C} \\   \\ \text{H}_2\text{C} \text{---} \text{ONO}_2 \end{array}$ H 4.1 $\begin{array}{c} \text{H}_2\text{C} \\   \\ \text{H}_2\text{C} \text{---} \text{O} \\   \\ \text{H}_2\text{C} \end{array}$ N 14.3 O 57.1 $\begin{array}{c} \text{H}_2\text{C} \\   \\ \text{H}_2\text{C} \text{---} \text{ONO}_2 \end{array}$ C/H Ratio 0.143	<b>Molecular Weight:</b> $(\text{C}_4\text{H}_8\text{N}_2\text{O}_7)$ 196	
	<b>Oxygen Balance:</b>	
	CO <sub>2</sub> % -41	
	CO % -8	
	<b>Density:</b> gm/cc <b>Liquid</b> 1.38	
	<b>Melting Point:</b> °C 2	
	<b>Freezing Point:</b> °C	
	<b>Boiling Point:</b> °C <b>Decomposes</b> 160	
	<b>Refractive Index:</b> $n_{D^2}^{20}$ $n_{D^2}^{25}$ 1.4498 $n_{D^2}^{20}$	
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe	<b>200 Gram Bomb Sand Test:</b> Sand, gm 42.2	
	<b>Rifle Bullet Impact Test:</b> Trials %	
	Explosions	
	Partials	
	Burned	
	Unaffected	
	<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)	
	1 5 237	
	10	
	15	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	<b>Ballistic Mortar, % TNT:</b> 90	
	<b>Treuzi Test, % TNT:</b> 77	
	<b>Plate Dent Test:</b> Method Condition Confinement Density, gm/cc	
	Brisance, % TNT	
	<b>Detonation Rate:</b> Confinement	
	Condition	
	Charge Diameter, in.	
	Density, gm/cc 1.38	
	Rate, meters/second 6760	
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 193		

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Diethylene Glycol Dinitrate (DEGN) Liquid

<b>Booster Sensitivity Test:</b> Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
<b>Heat of:</b> Combustion, cal/gm 2792 Explosion, cal/gm 841 Gas Volume, cc/gm 796 Formation, cal/gm 2020 Fusion, cal/gm	<b>Armor Plate Impact Test:</b>  <b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec Aluminum Fineness
<b>Specific Heat:</b> cal/gm. °C	<b>500-lb General Purpose Bomb:</b>  <b>Plate Thickness, inches:</b> 1 1½ 1¾ 2¼
<b>Burning Rate:</b> cm/sec	<b>Bomb Drop Test:</b>  <b>T7, 2000-lb Semi-Armor-piercing Bomb vs Concrete:</b> Max Safe Drop, ft
<b>Thermal Conductivity:</b> cal/sec/cm/°C	<b>500-lb General Purpose Bomb vs Concrete:</b>  <b>Height, ft</b> Tri. Unaffected Low Order High Order
<b>Coefficient of Expansion:</b> Linear, %/°C	  <b>1000-lb General Purpose Bomb vs Concrete:</b>  <b>Height, ft</b> Trials Unaffected Low Order High Order
<b>Volume, %/°C</b>	
<b>Hardness, Mohs' Scale:</b>	
<b>Young's Modules:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc	
<b>Compressive Strength:</b> lb/inch <sup>2</sup>	
<b>Vapor Pressure:</b> °C mm Mercury 20 0.0037 50 0.130	

Diethylene Glycol Dinitrate (DEGN) Liquid

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Gloss Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Colorless	
For Subject HE			
3 inch HE, M42A1 Projectile, Lot KC-5:		<b>Principal Uses:</b> Propellant compositions	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
		Method	Liquid
		Hazard Class (Quantity-Distance)	Class 9
<b>Blast (Relative to TNT):</b>		<b>Compatibility Group</b>	
Air:			
Peak Pressure			
Impulse			
Energy			
Air, Confined:			
Impulse			
Under Water:		<b>Preparation:</b> DEGN can be prepared with approximately 65% yield by adding diethyleneglycol to mixed acid (50% HNO <sub>3</sub> , 45% H <sub>2</sub> SO <sub>4</sub> , and 5% H <sub>2</sub> O). The temperature is kept at 30°C or lower. The separated DEGN is purified by washing with successive portions of water, dilute sodium carbonate solution and water until neutral.	
Peak Pressure			
Impulse			
Energy			
Underground:		<b>Hydrolysis, % Acid:</b>	
Peak Pressure		10 days at 22°C	0.003
Impulse		5 days at 60°C	0.003
Energy		<b>Solubility in Water, gm/100 gm, at:</b>	
		25°C	0.40
		60°C	0.60
<b>Viscosity, centipoises:</b>		<b>Solubility, gm/100 gm, at 25°C, in:</b>	
Temp, 20°C	6.1	Ether	00
		Alcohol	00
		2:1 Ether:Alcohol	00
		Acetone	00

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Diethylene Glycol Dinitrate (DEGN) Liquid

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 19, 925 (1927) and later by Rinkenbach and H. A. Aaronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

Destruction by Chemical Decomposition:

DEGN is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ). Heat is liberated by this reaction but this is not hazardous if stirring is maintained during the addition of DEGN and continued until solution is complete.

References:<sup>19</sup>

See the following Picatinny Arsenal Technical Reports on DEGN:

0	1	2	3	4	5	7	9
50	231	72	673	494	346	487	279
180	551	602	1443	1624	1516	1427	579
620	1391	1282			1616	1487	1439
1490	1421	1392			1786	1817	
1990							

<sup>19</sup> See footnote 1, page 10.

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

AMCP 706-177

<b>Composition:</b> % C 31.6 H 3.2 N 14.7 O 50.5 C/H Ratio  <b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 18	<b>Molecular Weight:</b> $(C_{10}H_{12}N_4O_{12})$ 380	
	<b>Oxygen Balance:</b> CO <sub>2</sub> % -59 CO % -17	
	<b>Density:</b> gm/cc Crystal 1.60	
	<b>Melting Point:</b> °C Form I 89 Form II 86	
	<b>Freezing Point:</b> °C	
	<b>Boiling Point:</b> °C	
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected  <b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>Refractive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>25</sup> n <sub>d</sub> <sup>30</sup>	
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 0.66 120°C ---- 135°C 0.91 150°C	
	<b>200 Gram Bomb Sand Test:</b> Sand, gm	
	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	<b>Ballistic Mortar, % TNT:</b>	
	<b>Troux Test, % TNT:</b>	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
	<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	
	<b>Flammability Index:</b>	
	<b>Hygroscopicity:</b> %	
	<b>Volatility:</b>	
	Density, gm/cc 1.49 Rate, meters/second 6050	

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Bis(2,2-Dinitropropyl) Fumarate (DNPF)

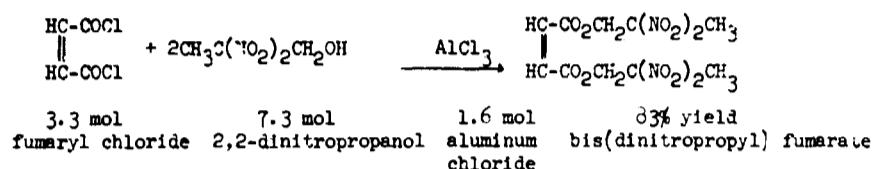
<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		White	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b>	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Cast	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		1.50	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	Dry
Peak Pressure			
Impulse			
Energy			
Air, Confined:		<b>Hazard Class (Quantity-Distance)</b>	
Impulse			
Under Water:		<b>Compatibility Grp. p</b>	
Peak Pressure			
Impulse			
Energy		Exudation	None
Underground:		<b>Heat of:</b>	
Peak Pressure		Combustion, cal/gm	3070
Impulse			(calculated)
Energy		Detonation, cal/gm	767
			(calculated)
		<b>Viscosity, poises:</b>	
		Temp. 98.9°C	0.56
		106.5°C	0.43
		<b>Liquid Density, gm/cc:</b>	
		Temp. 98.9°C	1.362
		106.5°C	1.375
		<b>Origin:</b>	
		Synthesized in 1952 by M. E. Hill of the U. S. Naval Ordnance Laboratory, White Oak, Maryland.	

#### Bis(2,2-Dinitropropyl) Fumarate (DNPF)

AMCP 706-177

Preparation:

(a, b)



Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poured into a bucket. As cooling took place the slurry was vigorously agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold HCl. The solid product was collected on a sintered funnel, washed with water and with hexane. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

### References:<sup>20</sup>

- (b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives. Navy Contract NORD-11280, Task A, 26 May 1954.

<sup>20</sup> See footnote 1, page 10.

Bis(2,2-Dinitropropyl) Succinate (DNPS)

<b>Composition:</b> %	<b>Molecular Weight:</b> $(C_{10}H_{14}N_4O_{12})$ 382
C 31.4	Oxygen Balance: CO <sub>2</sub> % -63
H 3.7	CO % -21
N 14.7	<b>Density:</b> gm/cc Crystal 1.51
O 50.2	<b>Melting Point:</b> °C 86
C/H Ratio 0.250	<b>Frosting Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg	<b>Boiling Point:</b> °C
Picatinny Arsenal Apparatus, in. Sample Wt, mg	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b> n <sub>20</sub> <sup>D</sup> n <sub>20</sub> <sup>D</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 0.10 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) --- 1 --- 5 >400 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
<b>73°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Troux Test, % TNT:</b>
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> %	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Volatility:</b>	

Bis(2,2-Dinitropropyl) Succinate (DNPS)

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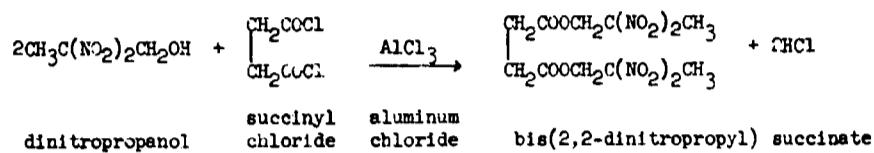
<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  3 inch HE, M43A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Gloss Cones      Steel Cones Hole Volume Hole Depth  <b>Color:</b> White
	<b>Principal Uses:</b>
	<b>Method of Loading:</b> Cast
	<b>Loading Density:</b> gm/cc
	<b>Storage:</b>  <b>Method:</b> Dry  <b>Hazard Class (Quantity-Distance):</b>  <b>Compatibility Group:</b>  <b>Exudation:</b> None
	<b>Origin:</b>  Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

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Bis(2,2-Dinitropropyl) Succinate (DNPS)

Preparation:

(a)



A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2 hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of DNPS (melting point 85° to 85.6°C).

References:<sup>21</sup>

- (a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

<sup>21</sup>See footnote 1, page 10.

2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPB)

AMCP 706-177

<p><b>Composition:</b>          %          C 23.6          H 2.5          N 19.7          O 54.2          C/H Ratio</p> <p><b>Impact Sensitivity, 2 Kg Wt:</b>          Bureau of Mines Apparatus, cm          Sample Wt 20 mg          Plastimine Arsenol Apparatus, in.          Sample Wt, mg</p> <p><b>Fiction Pendulum Test:</b>          Steel Shoe          Fiber Shoe</p> <p><b>BBM Bullet Impact Test:</b> Trials %          Explosions          Partially          Burned          Unaffected</p> <p><b>Explosion Temperature:</b> °C          Seconds, 0.1 (no cap used) ---          1 ---          5 300          10          15          20</p> <p><b>75°C International Heat Test:</b>          % Loss in 48 Hrs</p> <p><b>100°C Heat Test:</b>          % Loss, 1st 48 Hrs          % Loss, 2nd 48 Hrs          Explosion in 100 Hrs</p> <p><b>Flammability Index:</b></p> <p><b>Hygroscopicity:</b> %</p> <p><b>Volatility:</b></p>	<p><b>Molecular Weight:</b> (C<sub>7</sub>H<sub>9</sub>N<sub>5</sub>O<sub>12</sub>) 355</p> <p><b>Oxygen Balance:</b>          CO<sub>2</sub> % -29          CO % +2.3</p> <p><b>Density:</b> gm/cc Crystal 1.68</p> <p><b>Melting Point:</b> °C Form I 11 Form II 95          Form III 59</p> <p><b>Freezing Point:</b> °C</p> <p><b>Boiling Point:</b> °C</p> <p><b>Refractive Index:</b> n<sub>D</sub><sup>20</sup>          n<sub>D</sub><sup>25</sup>          n<sub>D</sub><sup>30</sup></p> <p><b>Vacuum Stability Test:</b>          cc/40 Hrs, at          90°C ---          100°C 0.5          120°C          135°C          150°C</p> <p><b>200 Gram Bomb Sand Test:</b>          Sand, gm</p> <p><b>Sensitivity to Ignition:</b>          Minimum Detonating Charge, gm          Mercury Fulminate          Lead Azide          Tetryl</p> <p><b>Ballistic Mortar, % TNT:</b></p> <p><b>Trund Test, % TNT:</b></p> <p><b>Plate Dent Test:</b>          Method          Condition          Confined          Density, gm/cc          Brisance, % TNT</p> <p><b>Detonation Rate:</b>          Confinement:          Condition          Charge Diameter, in.          Density, gm/cc 1.67          Rate, meters/second 7600</p>

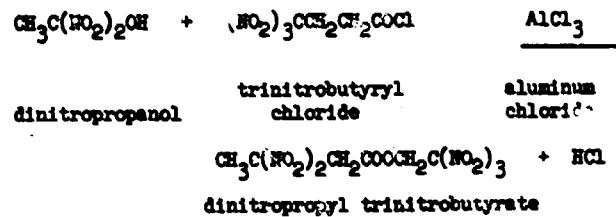
<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M62A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="0"> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table> <b>Color:</b> White	Glass Cones	Steel Cones	Hole Volume		Hole Depth																						
Glass Cones	Steel Cones																												
Hole Volume																													
Hole Depth																													
<b>Fragment Velocity, ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Principal Uses:</b>  <b>Method of Loading:</b> Cast  <b>Loading Density: gm/cc</b> 1.67  <b>Storage:</b> Method Dry																											
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse		<b>Hazard Class (Quantity-Distance)</b>  <b>Compatibility Group:</b>  <b>Exudation:</b> None																											
<b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<b>Heat of:</b> (c) <table border="0"> <thead> <tr> <th></th> <th colspan="2">Solvent</th> </tr> <tr> <th></th> <th>CCl<sub>4</sub></th> <th>DMF</th> </tr> </thead> <tbody> <tr> <td>I → III</td> <td>6.2</td> <td>4.8</td> </tr> <tr> <td>II → I</td> <td>-16.6</td> <td>-22.0</td> </tr> </tbody> </table> <b>Heat of Solution, 30°C:</b> <table border="0"> <thead> <tr> <th>Material</th> <th colspan="2">ΔH Solution, cal/gm</th> </tr> <tr> <th></th> <th>CCl<sub>4</sub></th> <th>DMF</th> </tr> </thead> <tbody> <tr> <td>Form III</td> <td>29.5</td> <td>8.1</td> </tr> <tr> <td>Form I</td> <td>35.6</td> <td>12.8</td> </tr> <tr> <td>Form II</td> <td>19.1</td> <td>-9.1</td> </tr> </tbody> </table> <b>Origin:</b> Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.		Solvent			CCl <sub>4</sub>	DMF	I → III	6.2	4.8	II → I	-16.6	-22.0	Material	ΔH Solution, cal/gm			CCl <sub>4</sub>	DMF	Form III	29.5	8.1	Form I	35.6	12.8	Form II	19.1	-9.1
	Solvent																												
	CCl <sub>4</sub>	DMF																											
I → III	6.2	4.8																											
II → I	-16.6	-22.0																											
Material	ΔH Solution, cal/gm																												
	CCl <sub>4</sub>	DMF																											
Form III	29.5	8.1																											
Form I	35.6	12.8																											
Form II	19.1	-9.1																											

2,2-Dinitropropyl-4,4,4-Tinitrobutyrate (DNPTB)

AMCP 706-177

Preparation:

(a, b)



Dinitropropanol, trinitrobutyryl chloride and aluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture was refluxed at 75°C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by azeotropic distillation before the acid chloride was added. The purified product had a melting point of 95° to 96°C.

Crystallographic Data: (c)

Three distinct crystallographic modifications of DNPTB have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chlorobenzene, acetone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DNPTB, Form II is always observed.

Linear Rate of Transformation of Form II to Form I (c)

Temperature, °C	Average Rate, sq inch/hour	Standard Deviation	Average Rate, mm/hour
15	0.347	0.036	0.012
20	0.435	0.025	0.128
25	0.452	0.048	0.133
30	0.475	0.049	0.140
35	0.253	0.037	0.015

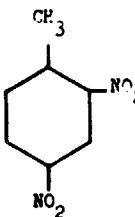
Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DNPTB, gave consistent sensitivity values.

References:<sup>22</sup>

- (a) W. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.
- (b) W. B. Hewson, Hercule Report on High Explosives, Navy Contract NORD-11280, Task A, 18 October 1954.
- (c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, NAVORD Report No. 6427, 11 December 1956.

<sup>22</sup>See footnote 1, page 10.

2,4-Dinitrotoluene (DNT)

<b>Composition:</b> % C 46.3 H 3.3 N 15.4 O 35.0 C/H Ratio 0.579		<b>Molecular Weight:</b> (C <sub>7</sub> H <sub>6</sub> N <sub>2</sub> O <sub>4</sub> ) 1.82
		<b>Oxygen Balance:</b> CO <sub>2</sub> % -114 CO % - 53
		<b>Density:</b> gm/cc 1.521
		<b>Melting Point:</b> °C 71
		<b>Frosting Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		<b>Boiling Point:</b> °C Decomposes 300
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected		<b>Refractive Index:</b> n <sub>D</sub> n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub>
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials 0 Burned 0 Unaffected 100		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 0.04 135°C 150°C
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Decomposes 310 10 15 20		<b>200 Gram Bomb Sand Test:</b> Sand, gm 19.3
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		<b>Ballistic Mortar, % TNT:</b> (a) 71 <b>Treuzzi Test, % TNT:</b> (b) 64
<b>Flammability Index:</b>		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> % 25°C, 100% RH 0.00		
<b>Volatility:</b>		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

## 2,4-nitrotoluene (TNT)

AMCP 706-177

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Yellow	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-S:</b>		<b>Principal Uses:</b>	
Density, gm/cc		Ingredient of propellant powder, dynamites and plastic explosives	
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Pressed, extruded or cast composition	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		Variable	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	Dry
Peak Pressure			
Impulse		Hazard Class (Quantity-Distance)	Class 12
Energy		Compatibility Group	Group D
Air, Confined:		Exudation	
Impulse			
Under Water:		<b>65.5°C KI Test:</b>	
Peak Pressure		Minutes	60+
Impulse			
Energy		Heat of:	
Underground:		Combustion, cal/gm (b)	1545
Peak Pressure			
Impulse		Thermal Conductivity:	
Energy		cal, sec/cm/ <sup>0</sup> C	
		Density 1.322 gm/cc	6.28 x 10 <sup>-4</sup>

2,4-Dinitrotoluene (DNT)Preparation:

See TNT.

Solubility: gm/100 gm of the following substances:

<u>Methyl Alcohol</u>		<u>Nitroglycerin</u>		<u>Water</u>	
<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</u>
25	0.16	20	30	22	0.027
35	0.29			50	0.037
45	0.49			100	0.254
55	0.77				
60	1.03				

Solubility at 15°C, in:

<u>Solvent</u>	<u>g</u>	<u>Solvent</u>	<u>g</u>
CHCl <sub>3</sub>	65.076	C <sub>2</sub> H <sub>5</sub> OH (absolute)	3.039
C <sub>2</sub> H <sub>4</sub>	2.431	Ether (absolute)	2.422
C <sub>6</sub> H <sub>6</sub>	60.644	Acetone	81.911
Toluol	45.470	Ethyl acetate	57.929
CH <sub>3</sub> OH	5.014	CS <sub>2</sub>	2.306
C <sub>2</sub> H <sub>5</sub> OH (96%)	1.916	Pyridine	76.810

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DNT and other isomers of DNT. Also occurs as an impurity in crude TNT obtained by standard manufacturing process. Used in explosive mixtures at least since 1931.

References:<sup>23</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) A. H. Klatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
- (c) Report AC-2861.
- (d) Also see the following Picatinny Arsenal Technical Reports on DNT:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
810	1351	72	43	394	1615	186	97	768	69
1830	1501	372	233	804	2125	1556	817	938	149
	1651	922	343	1044		1816	837	1538	249
	1781	1142	673	1084		1896			279
	1821	1672	1023	1004					779
	2031	1692	1663	1164					1749
	2221		1743	1324					
			2013	1464					
				1524					
				1674					
				1754					
				2094					

<sup>23</sup>See footnote 1, page 10.

Dipentaerythritol Hexanitrate (DPEHN)

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<b>Composition:</b> %	<b>Molecular Weight: (C<sub>10</sub>H<sub>16</sub>N<sub>6</sub>O<sub>19</sub>) 554</b>	
C 21.7	ONO <sub>2</sub>	ONO <sub>2</sub>
H 2.9	CH <sub>2</sub>	CH <sub>2</sub>
N 15.2		
O 60.2	ON <sub>2</sub> CH <sub>2</sub> C - CH <sub>2</sub> - C - CH <sub>2</sub> - CCH <sub>2</sub> ONO <sub>2</sub>	ON <sub>2</sub>
C/H Ratio 0.15 <sup>b</sup>	ONO <sub>2</sub>	ONO <sub>2</sub>
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 14 Sample Wt 20 mg	<b>Balancing Agent:</b> Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 10	<b>Oxygen Balance:</b> CO <sub>2</sub> % -26 CO % > 3
		<b>Density: gm/cc</b> Crystal 1.63
	<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe Unaffected	<b>Melting Point: °C</b> 73.7
		<b>Freezing Point: °C</b>
	<b>2000 Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>Boiling Point: °C</b>
		<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup>
	<b>200 Gram Bomb Sand Test:</b> Sand, gm 57.4	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 3.7 120°C 11+ 135°C 150°C
		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
	<b>Ballistic Mortar, % TNT:</b> (a) 142 <b>Trend Test, % TNT:</b> (b) 128	<b>Ballistic Mortar, % TNT:</b> (a) 142 <b>Trend Test, % TNT:</b> (b) 128
		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brionce, % TNT
	<b>Flammability Index:</b>	<b>Detonation Rate:</b> (c) Confinement Copper tube Condition Pressed
		Charge Diameter, in. 0.39 Density, gm/cc 1.59 Rate, meters/second 7410
<b>Hygrosopicity: %</b>	0.03	
<b>Vaporility:</b>		

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth	
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Color:</b> White	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb		<b>Principal Uses:</b> Ingredient of priming compositions	
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Method of Loading:</b> Pressed	
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Loading Density: gm/cc</b> At 3000 to 4000 psi      1.59	
<b>Blow (Relative to TNT):</b>  Air: Peak Pressure Impulse Energy		<b>Storage:</b>  <b>Method:</b> Dry	
<b>Air, Continued:</b> Impulse		<b>Hazard Class (Quantity-Distance):</b> Class 9	
<b>Under Water:</b> Peak Pressure Impulse Energy		<b>Compatibility Group:</b> Inundation	
<b>Underground:</b> Peak Pressure Impulse Energy		<b>Preparation:</b> (Chemistry of Powder and Explosives, Davis)  $2(\text{HO}-\text{CH}_2)_4\text{C} \xrightarrow{\text{Dehydration}} (\text{HO}-\text{CH}_2)_3\text{C}-\text{O}-\text{C}(\text{CH}_2-\text{OH})_3 \longrightarrow (\text{O}_2\text{NO}-\text{CH}_2)_3\text{C}-\text{O}-\text{C}(\text{CH}_2-\text{ONO}_2)_3$	
		<b>Dipentaerythritol Hexanitrate</b> is procured in the pure state (melting point 72°C) by fractional crystallization of crude PEHN from moist acetone.	
		<b>Origin:</b> Formed as an impurity in the preparation of PEHN. Properties first described by W. Frederick and W. Brün in 1930 (Berichte 63, 2861 (1930); Z. ges Schieß-Sprengstoffw 27, 73-6, 125-7, 156-8 (1932)).	
		<b>Heat of:</b> Combustion, cal/gm      2260	

Dipentaerythritol Hexanitrate (DPEHN)

AMCP 706-177

References:<sup>24</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) A. Stettbacher, Die Schiess und Sprengstoffe, Leipzig, p. 363.
- (c) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-223.
- (d) R. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

<sup>24</sup>See footnote 1, page 10.

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Dynamite, Low Velocity, Picatinny Arsenal (LVD)

<b>Composition:</b> 99.5/0.5 RDX/l-MA dye*      17.5 % TNT      67.8 Tripentaerythritol      8.6 68/32 Vistac No 1/DOS binders**      4.1 Cellulose acetate, LH-1      2.0	<b>Molecular Weight:</b>
*RDX, Class E; l-MA is 96% pure l-methylaminoanthraquinone. **Vistac No 1 is low MW polybutene; DOS is dioctylsebacate.	<b>Oxygen Balance:</b> CO <sub>2</sub> % CO %
C/H Ratio	<b>Density:</b> gm/cc      Loading      0.9
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg      22 Picatinny Arsenal Apparatus, in.      22 Sample Wt, mg      19	<b>Melting Point:</b> °C <b>Freezing Point:</b> °C <b>Boiling Point:</b> °C
Friction Pendulum Test: Steel Shoe      Unaffected Fiber Shoe      Unaffected	<b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>28</sup>
Rifle Bullet Impact Test:      Trials Explosions      % Partials Burned Unaffected	<b>Versum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C      0.90 135°C 150°C
75°C International Heat Test: % Loss in 48 Hrs	<b>200 Gram Bomb Sand Test:</b> Sand, gm      40.5
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide      0.20 Tetryl      0.15 <b>Burnish Starter, % TNT:</b> 92 <b>Tressel Test, % T.T.:</b> <b>Plate Dot Test.</b> Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	<b>Detonation Rate:</b> Confinement      None Condition      Hand tamped Charge Diameter, in.      1.25 Density, gm/cc      0.9 Rate, meters/second 4397; or 14400 ft./sec
Hygroscopicity: % 71°C, 95% RH, 30 days      0.31 Satisfactory	
Volatility:	

Dynamite, Low Velocity, Picatinny Arsenal (LVD)

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<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M62A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  <b>Color:</b> Pink  <b>Principal Uses:</b> Excavation, demolition, and cratering  <b>Method of Loading:</b> Bell Packer machine loaded  <b>Loading Density:</b> gm/cc      0.9 Tamped cartridge 1-1/2" diameter, 8" long  <b>Storage:</b> Method      Dry  <b>Hazard Class (Quantity-Distance):</b> Class 9  <b>Compatibility Group:</b> Group A  <b>Exudation:</b>  <b>Sensitivity to Initiation:</b> Stick dry, No. 6 Electric cap      Positive Stick dry, Corps of Engineers      Positive Stick wet, Corps of Engineers      Positive  <b>Air Gap Propagation:</b> Max distance will, inch      2-1/2 min distance will not, inch      3  <b>Stick Water Immersion:</b> Weight gain, %      9-16  <b>Heat of:</b> Explosion, cal/gm      625 Gas Volume, cc/gm      611  <b>Cold Storage:</b> Plastic to -65°F  <b>Low Temperature Usage:</b> -65°F, 1 day, M2 cap crimp      Satisfactory
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Dynamite, Low Velocity, Picatinny Arsenal (WD)

Preparation:

To date this dynamite has been prepared on a laboratory scale, the details of which are classified. It has been shown, however, to be machine loadable on a Hall packing machine.

Origin:

Nobel invented the original dynamite in 1866 and gave the name dynamite to mixtures of nitroglycerin and kieselguhr. The strength of a dynamite was indicated by the percentage of NG in the mixture. Later oxidants and combustibles were substituted for the kieselguhr, and ammonium nitrate and/or nitrostarch replaced the NG, bringing into existence new types of dynamites. World War II military operations required special demolition and cratering explosives free from the objectionable characteristics of NG and many "dynamite substitutes" were developed for specific applications. The subject low velocity dynamite was developed in 1956 by Picatinny Arsenal. (Ref a).

References: <sup>25</sup>

(a) H. W. Velt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report 2374, March 1957.

(b) Also see the following Picatinny Arsenal Technical Reports on Dynamites:

0	1	2	4	2	6	7	8	9
1260	1381	782	864	1285	1416	507	848	1819
1360	1611	1531	1464		1436	957	1828	
1720					1506			
1760					2056			

<sup>25</sup>See footnote 1, page 10.

Dynamite, Medium Velocity, Hercules (MVD)

AMCP 706-177

<b>Composition:</b> % NDX 75 TNT 15 Starch 5 SAE No. 10 Oil 4 Vistanex oil gel* 1  *80/15/5, SAE No. 10 weight oil/Vistanex B-120XC/Navy D2 wax. C/H Ratio	<b>Molecular Weight:</b>  <b>Oxygen Balance:</b> CO: % -51 CO %
	<b>Density:</b> gm/cc <b>Loading:</b> 1.1
	<b>Melting Point:</b> °C
	<b>Frosting Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm >100 Sample Wt 20 mg 18 Picatinny Arsenal Apparatus, in. 25 Sample Wt, mg	<b>Nitroglycerin Equivalent, %</b> 60  <b>Refractive Index, n<sub>D</sub>:</b> n <sub>D</sub> n <sub>D</sub> n <sub>D</sub>
<b>Friction Pendulum Test:</b> Steel Shoe Crackles Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.80 120°C 0.94 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials 0 Burned 10 Unaffected 90	<b>200 Gram Bomb Sand Test:</b> Sand, gm 52.6
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10  <b>Ballistic Mortar, % TNT:</b> 122
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Trend Test, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.62 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brinell, % TNT
<b>Flammability Index:</b>	
<b>Hygroscopicity:</b> % 71°C, 95% RH, 30 days Satisfactory	<b>Detonation Rate:</b> Confinement None Condition Machine tamped Charge Diameter, in. 1.50 Density, gm/cc 1.1 Rate, meters/second 6000-6600; or 20,000 ft/sec
<b>Volatility:</b>	

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Dynamite, Medium Velocity, Hercules (MVD)

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M43A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE																																																										
<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <table border="1"> <tr> <td>Color:</td> <td>Buff</td> </tr> </table> <table border="1"> <tr> <td>Principal Uses:</td> <td>Excavation, demolition, and cratering</td> </tr> </table> <table border="1"> <tr> <td>Method of Loading:</td> <td>Hall Packer machine loaded</td> </tr> </table> <table border="1"> <tr> <td>Loading Density: gm/cc</td> <td>1.1</td> </tr> <tr> <td colspan="2">Cartridge 1-1/2" diameter, 8" long</td> </tr> </table> <table border="1"> <tr> <td>Storage:</td> <td></td> </tr> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group A</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table> <table border="1"> <tr> <td>Sensitivity to Initiation:</td> <td></td> </tr> <tr> <td>Stick dry, No. 6 Electric cap</td> <td>Positive</td> </tr> <tr> <td>Stick dry, Corps of Engineers</td> <td>Positive</td> </tr> <tr> <td>Stick wet, Corps of Engineers</td> <td>&gt; 50% Positive</td> </tr> </table> <table border="1"> <tr> <td>Air Gap Propagation:</td> <td></td> </tr> <tr> <td>Max distance will, inch</td> <td>1</td> </tr> <tr> <td>Min distance will not, inch</td> <td>2-1/2</td> </tr> </table> <table border="1"> <tr> <td>Quarry Performance:</td> <td>4 tons rock/ton explosive</td> </tr> </table> <table border="1"> <tr> <td>Stick Water Immersion:</td> <td></td> </tr> <tr> <td>Weight gain, %</td> <td>25-27</td> </tr> </table> <table border="1"> <tr> <td>Heat of:</td> <td></td> </tr> <tr> <td>Explosion, cal/gm</td> <td>935</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>945</td> </tr> </table> <table border="1"> <tr> <td>Cold Storage:</td> <td>Plastic to -70°F</td> </tr> </table> <table border="1"> <tr> <td>Low Temperature Usage:</td> <td></td> </tr> <tr> <td>-65°F, 1 day, M2 cap crimp</td> <td>Satisfactory</td> </tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth		Color:	Buff	Principal Uses:	Excavation, demolition, and cratering	Method of Loading:	Hall Packer machine loaded	Loading Density: gm/cc	1.1	Cartridge 1-1/2" diameter, 8" long		Storage:		Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group A	Exudation		Sensitivity to Initiation:		Stick dry, No. 6 Electric cap	Positive	Stick dry, Corps of Engineers	Positive	Stick wet, Corps of Engineers	> 50% Positive	Air Gap Propagation:		Max distance will, inch	1	Min distance will not, inch	2-1/2	Quarry Performance:	4 tons rock/ton explosive	Stick Water Immersion:		Weight gain, %	25-27	Heat of:		Explosion, cal/gm	935	Gas Volume, cc/gm	945	Cold Storage:	Plastic to -70°F	Low Temperature Usage:		-65°F, 1 day, M2 cap crimp	Satisfactory
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Dynamite, Medium Velocity, Hercules (MVD)

AMCP 706-177

Preparation:

Manufactured on standard dynamite line and packaged on a Hall packing machine. Details of handling materials and techniques of manufacture are classified.

Origin:

Military forces frequently require excavation, demolition, and cratering operations for which standard high explosives are unsuitable. Commercial blasting explosives, except black powder, are called dynamites although they may contain no nitroglycerin. The subject dynamite substitute was developed in 1952 by the Hercules Powder Company (Ref a).

References: 26

(a) W. R. Baldwin, Jr., Blasting Explosives (Dynamite Substitute), Hercules Powder Company Formal Progress Report, RI 2086, 15 August 1952, Army Contract DA-36-034-ORD-110.

(b) H. W. Voigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report No. 2374, March 1957.

<sup>26</sup>See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b> Approximately 503
Nitrocellulose, 13.25% N	80	Oxygen Balance: CC, % +5 CO % -25
Barium Nitrate	8	Density: gm/cc
Potassium Nitrate	8	Melting Point: °C
Starch	3	Freezing Point: °C
Diphenylamine	0.75	Boiling Point: °C
Aurine	0.25	Refractive Index, $n_{D}^{20}$ $n_{D}^{25}$ $n_{D}^{20}$
<b>C/H Ratio:</b>		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	19	<b>200 Gram Bomb Sand Test:</b> Sand, gm 46.8
Sample Wt 20 mg		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm
Picatinny Arsenal Apparatus, in.		Mercury Fulminate 0.22
Sample Wt, mg	20	Lead Azide
<b>Friction Pendulum Test:</b>		Tetryl
Steel Shoe	Snaps	<b>Ballistic Mortar, % TNT:</b>
Fiber Shoe		<b>Troux Test, % TNT:</b>
<b>Rifle Bullet Impact Test:</b>	Trials	<b>Plate Dent Test:</b>
	%	Method
Explosions		Condition
Partials		Confined
Burned		Density, gm./cc
Unaffected		Brisance, % TNT
<b>Explosion Temperature:</b> °C		<b>Detonation Rate:</b>
Seconds, 0.1 (no cap used)		Confinement
1		Condition
5 Decomposes	200	Charge Diameter, in.
10		Density, gm/cc
15		Rate, meters/second
20		
<b>75°C International Heat Test:</b>		
% Loss in 48 Hrs	1.8	
<b>100°C Heat Test:</b>		
% Loss, 1st 48 Hrs	2.0	
% Loss, 2nd 48 Hrs	0.2	
Explosion in 100 Hrs	None	
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> % 30°C, 90% RH	6.2	
<b>Volatility:</b>		

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M43A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p> <p><b>Blow (Relative to TNT):</b></p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><b>References:</b><sup>27</sup>(a) See the following Picatinny Arsenal Technical Reports on EC Blank Fire: 891, 901, 372, 512, 822, 233, 1373, 854, 65, 667, 817, 69, 579 and 1399.</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volumes</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <p><b>Color:</b></p> <p><b>Principal Uses:</b> Grenades; caliber .30 blank</p> <p><b>Mother of Loading:</b> Loose</p> <p><b>Loading Density: gm/cc</b> 0.40</p> <p><b>Storage:</b></p> <p>Method Wet</p> <p>Hazard Class (Quantity-Distance) Class 0</p> <p>Compatibility Group Group J</p> <p><b>Exudation</b></p> <p><b>Preparation:</b> EC Blank Fire is a partially colloided propellant manufactured by a process using either acetone and ethanol or a mixture of butyl acetate and benzene to gelatinize only a part of the nitrocellulose. The process is controlled so that the product passes through a No. 12 sieve and is retained on a No. 50 sieve.</p> <p><b>Origin:</b></p> <p>Invented in 1882 as bulk sporting (smokeless) powder by W. F. Reid and D. Johnson at the Explosive Company (whence the name "PC") in England (British Patent 619).</p> <p><b>120°C Heat Test:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Minutes</th> </tr> </thead> <tbody> <tr> <td>Salmon Pink</td> <td>150</td> </tr> <tr> <td>Red Fumes</td> <td>300+</td> </tr> <tr> <td>Explodes</td> <td>300+</td> </tr> </tbody> </table>	Glass Cones	Steel Cones	Hole Volumes		Hole Depth			Minutes	Salmon Pink	150	Red Fumes	300+	Explodes	300+
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Hole Volumes															
Hole Depth															
	Minutes														
Salmon Pink	150														
Red Fumes	300+														
Explodes	300+														

<sup>27</sup>See footnote 1, page 1C.

<b>Composition:</b> % Haleite (Ethylene Dinitramine) 55 TNT 45  C/H Rat.	<b>Molecular Weight:</b> 178
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg	<b>Oxygen Balance:</b> CO <sub>2</sub> % -51 CO % -17
Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	<b>Density:</b> gm/cc Cast 1.62
	<b>Melting Point:</b> °C Eutectic 80
	<b>Freezing Point:</b> °C
	<b>Boiling Point:</b> °C
	<b>Refractive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>25</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 1.0 120°C 11+ 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % 0 Partials 0 Burned 7 Unaffected 93	<b>200 Gram Bomb Sand Test:</b> Sand, gm 49.4
<b>Explosion Temperature:</b> * °C Seconds, 0.1 (no cap used) 435 1 248 5 Decomposes 190 10 183 15 176 20 168	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.26* Tetryl *Alternative initiating charges.
*Composition Haleite/TNT, 60/40.	<b>Ballistic Mortar, % TNT:</b> (a) 119 <b>Trouxi Test, % TNT:</b> (b) 120
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Match Box Test:</b> 52/48 Method B Condition Cast Confined No Density, gm/cc 1.62 Brisance, % TNT 112
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None	<b>Detonation Rate:</b> Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.63 Rate, meters/second 7340
<b>Flammability Index:</b> Will not continue to burn	
<b>Hygroscopicity:</b> % None	
<b>Volatility:</b>	

<u>Fragmentation Test:</u>			<u>Shaped Charge Effectiveness, TNT = 100: 50/50</u>	
90 mm HE, M71 Projectile, Lot WC-91:			Glass Cones	Steel Cones
Density, gm/cc	1.56	1.62	Hole Volume	126 123
Charge Wt, lb	2.065	2.092	Hole Depth	117 121
<u>Total No. of Fragments:</u>			<u>Color:</u> Yellow	
For TNT	703	703		
For Subject HE	842	902		
<u>3 inch HE, M43A1 Projectiles, Lot KC-5:</u>			<u>Principal Uses:</u> Projectiles, bombs; special ammunition components	
Density, gm/cc	1.60			
Charge Wt, lb	0.845			
<u>Total No. of Fragments:</u>			<u>Method of Loading:</u> Cast	
For TNT	514			
For Subject HE	536			
<u>Fragment Velocity: ft/sec</u>			<u>Loading Density: gm/cc</u> 1.65	
At 9 ft	2730			
At 25½ ft	2430			
Density, gm/cc	1.62			
<u>Blast (Relative to TNT):</u> (d, e)			<u>Storage:</u>	
Air:			Method Dry	
Peak Pressure	108			
Impulse	110			
Energy	108			
Air, Confined:			<u>Hazard Class (Quantity-Distance)</u> Class 9	
Impulse				
Under Water:			<u>Compatibility Group</u> Group I	
Peak Pressure	--			
Impulse	--			
Energy	113		<u>Exudation</u> Does not exude at 65°C	
Underground:				
Peak Pressure				
Impulse				
Energy				
<u>Booster Sensitivity Test:</u> (d)			<u>Eutectic Temperature, °C:</u> 79.8 gm Haleite/100 gm TNT 79.8°C 0.48 95.0°C 1.12	
Condition	Cast			
Tetryl, gm	100			
Wax, in. for 50% Detonation	1.28			
Density, gm/cc	1.62			
			<u>Compatibility with Metals:</u>  Dry: Brass, aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint, and mild steel plated with cadmium or nickel are unaffected. Copper, magnesium, magnesium-aluminum alloy and mild steel plated with copper or zinc are slightly affected.  Wet: Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are heavily attacked. Aluminum is slightly affected and stainless steel is unaffected.	

Preparation:

Wet Haleite is added slowly to molton TNT heated at about 100°C in a steam jacketed melting kettle equipped with a stirrer. Heating and stirring are continued until all moisture is evaporated. Loading is done by pouring the mixture cooled to 85°C.

Origin:

Mixtures of Haleite (EDNA) and TNT, designated Ednatol, were developed at Picatinny Arsenal just prior to World War II.

References:<sup>28</sup>

- (a) L. C. Smith and E. G. Kyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, ROL Memo 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.

(h) Also see the following Picatinny Arsenal Technical Reports on Ednatol:

0	1	2	3	4	5	6	7	8	9
1290	1291	1162	1193	1294	1325	1796	1457	1198	1279
1400	1451	1372	1363	1434	1395		1477	1388	1469
1420	1651	1482	1493		1885		1737	1838	
1530						1797			

<sup>28</sup>See footnote 1, page 10.

Ethylene Glycol Di-Trinitrobutyrate (GTEB)

AMCP 706-177

<b>Composition:</b> %	<b>Molecular Weight: (C<sub>10</sub>H<sub>12</sub>N<sub>6</sub>O<sub>16</sub>)</b>		468
C 25.6	CO <sub>2</sub> %	-34	
H 2.6	CO %	0	
N 17.1	<b>Density: gm/cc</b>	Crystal	1.63
O 54.7	<b>Melting Point: °C</b>		,96
C/H Ratio 0.235	<b>Freezing Point: °C</b>		
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg	<b>Boiling Point: °C</b>		
Picatinny Arsenal Apparatus, in. Sample Wt, mg	<b>Refractive Index, n<sub>D<sup>20</sup></sub></b>	n <sub>D<sup>20</sup></sub>	
		n <sub>D<sup>25</sup></sub>	
		n <sub>D<sup>30</sup></sub>	
<b>Fricton Pendulum Test:</b> Steel Shoe	<b>Vacuum Stability Test:</b>		
Fiber Shoe	cc/40 Hrs, at		
	90°C		
	100°C		
	120°C		
	135°C		
	150°C		
<b>Rifle Bullet Impact Test:</b> Trials	<b>200 Gram Bomb Sand Test:</b>		
Explosions %	Sand, gm		
Partials			
Burned			
Unaffected			
<b>Explosion Temperature:</b> °C	<b>Sensitivity to Initiation:</b>		
Seconds, 0.1 (no cap used) ---	Minimum Detonating Charge, gm		
1 ---	Mercury Fulminate		
5 50% point 230	Lead Azide		
10	Tetryl		
15			
20			
<b>75°C Interaction Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>		
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	<b>Trend Test, % TNT:</b>		
% Loss, 2nd 48 Hrs	<b>Plate Dent Test:</b>		
Explosion in 100 Hrs	Method		
	Condition		
	Confined		
	Density, gm/cc		
	Brisance, % TNT		
<b>Flammability Index:</b>	<b>Detonation Rate:</b>		
<b>Hygroscopicity:</b> %	Confinement		
<b>Volatility:</b>	Condition		
	Charge Diameter, in.		
	Density, gm/cc	1.63	
	Rate, meters/second	7340	

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="0"> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table> <b>Color:</b>  <b>Principal Uses:</b> Casting medium for HE compounds		Glass Cones	Steel Cones	Hole Volume		Hole Depth			
Glass Cones	Steel Cones										
Hole Volume											
Hole Depth											
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Method of Loading:</b> Cast  <b>Loading Density: gm/cc</b> 1.60									
<b>Storage:</b>  <b>Method</b> Dry		<b>Hazard Class (Quantity-Distance)</b>  <b>Compatibility Group</b>  <b>Exudation</b> None									
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse		<b>Preparation:</b> (a)  By the addition of nitroform to ethylene glycol diacrylate. As the method of preparation often leads to products difficult to purify, a preparation from ethylene glycol and pure trinitrobutyric acid is in process.									
<b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<b>Origin:</b>  First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey.									
<b>Viscosity, poises:</b> <table border="0"> <tr> <td>Temp, 98.9°C</td> <td>0.246</td> </tr> <tr> <td>106.5°C</td> <td>0.193</td> </tr> </table> <b>Liquid Density, gm/cc:</b> <table border="0"> <tr> <td>Temp, 98.9°C</td> <td>1.467</td> </tr> <tr> <td>106.5°C</td> <td>1.459</td> </tr> </table>		Temp, 98.9°C	0.246	106.5°C	0.193	Temp, 98.9°C	1.467	106.5°C	1.459		
Temp, 98.9°C	0.246										
106.5°C	0.193										
Temp, 98.9°C	1.467										
106.5°C	1.459										

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

AMCP 706-177

References:<sup>29</sup>

(a) U. S. Rubber Company Progress Report No. 14, Navy Contract NOrd-10129, 1 February 1951 to 1 May 1951.

(b) U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, Letter from Dr. O. H. Johnson to Commanding Officer, Picatinny Arsenal, 8 April 1955 (ORDBB 471.86/44-3, Registry No. 39815); and NOL Letter from Dr. D. V. Sickman to Commanding Officer, Picatinny Arsenal, 29 November 1955 (ORDBB 471.86/159-1; Serial No. 32894).

<sup>29</sup>See footnote 1, page 10.

Explosive D (Ammonium Picrate)

<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>6</sub> N <sub>4</sub> O <sub>7</sub> ) 246
C 29.3	Oxygen Content: CO <sub>2</sub> % -52
H 2.4	CO % -13
N 22.7	<b>Density:</b> gm/cc <b>Crystal</b> 1.72
O 45.6	<b>Melting Point:</b> °C <b>Decomposes</b> 265
C/H Ratio 0.317	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg      17 Picatinny Arsenal Apparatus, in. Sample Wt, mg      18	<b>Boiling Point:</b> °C
<b>Friction Perfection Test:</b> Steel Shoe      Unaffected Fiber Shoe      Unaffected	<b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup> a <sub>o</sub> 1.508 b <sub>o</sub> 1.870 c <sub>o</sub> 1.907
<b>Rifle Bullet Impact Test:</b> Trials Explosions % 0 Partials 0 Burned 30 Unaffected 70	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.4 135°C 150°C 0.4
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 405 1 367 5 Decomposes 318 10 314 15 299 20 295	<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate Lead Azide 0.20 Tetryl 0.06
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Meter, % TNT:</b> (a) 99
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None	<b>Trexel Test, % TNT:</b> <b>Plate Dear Test:</b> Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 91
<b>Flammability Index:</b>	<b>Detonation Rate:</b> Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.55 Rate, meters/second 6850
<b>Hygroscopicity:</b> % 100% RH 0.1	
<b>Volatility:</b>	

Explosive D (Ammonium Picrate)

AMCP 706-177

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>					
90 mm HE, M71 Projectile, Lot WC-93:		Glass Cones	Steel Cones				
Density, gm/cc	1.50						
Charge Wt, lb	1.94	Hole Volume					
Total No. of Fragments:		Hole Depth					
For TNT	703						
For Subject HE	649	Color:	Yellow-orange				
3 inch HE, M42A1 Projectile, Lot KC-5:		<b>Principal Uses:</b> AP projectiles and bombs					
Density, gm/cc	1.55						
Charge Wt, lb	0.82						
Total No. of Fragments:							
For TNT	514	<b>Method of Loading:</b> Pressed					
For Subject HE	508						
<b>Fragment Velocity: ft/sec.</b>		<b>Loading Density: gm/cc      psi <math>\times 10^3</math></b>					
At 9 ft		3	5	10	12	15	20
At 25½ ft		1.33	1.41	1.47	1.49	1.51	1.53
Density, gm/cc		<b>Storage:</b>					
		Method	Dry				
		Hazard Class (Quantity-Distance)	Class 9				
		Compatibility Group	Group I				
		Irradiation	None at 65°C				
<b>Blast (Relative to TNT):</b>		<b>Sensitivity to Electrostatic Discharge, Joules:</b> (d)					
Air:		<u>Through 100 Mesh:</u>					
Peak Pressure		Confined	6.0				
Impulse		Unconfined	0.025				
Energy		<b>Booster Sensitivity Test:</b> (c)					
Air, Confined:		Condition	Pressed				
Impulse		Tetryl, gm	100				
Under Water:		Wax, in. for 50% Detonation	1.27				
Peak Pressure		Density, gm/cc	1.54				
Impulse		<b>Heat of:</b>					
Energy		Combustion, cal/gm	2890				
Underground:		Explosion, cal/gm	800				
Peak Pressure		Formation, cal/gm	395				
Impulse							
Energy							

Explosive D (Ammonium Picrate)Preparation:

Explosive D is manufactured by suspending picric acid in hot water and neutralizing it with gaseous or liquid ammonia. As the picrate is formed, it goes into solution; on cooling, it precipitates. An excess of ammonia leads to formation of the red form of ammonium picrate. This should be avoided. The separated crystals are washed with cold water and dried.

Effect of Storage on Sand Test Values:

Storage Years	°C	Minimum Detonating Charge		Sand Crushed (gm)
		Mercury Fulminate (gm)	Tetryl (gm)	
0			0.06	23
3.5	50	0.25		23
2 *	Normal		0.03	23
4 *	Normal		0.04	23
2 **	50	0.24		23

\* After 3.5 years at 50°C.

\*\* After 3.5 years at 50°C and 2 years at magazine temperature.

Solubility: gm/100 gm (%), or: (e)

Water		Alcohol		Ethyl Acetate	
°C	%	°C	%	°C	%
20	1.1	0	0.215	0	0.290
100	75	10	0.690	10	0.300
		30	1.050	30	0.380
		50	1.890	50	0.450
		80	3.620	80	0.560

Origin:

First prepared by Marchand in 1841 and used by Brugere in admixture with potassium nitrate as a propellant in 1869. Used as a high explosive after 1900.

Destruction by Chemical Decomposition:

Explosive D (ammonium picrate) is decomposed by dissolving in 30 times its weight of a solution made from 1 part of sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) in 6 parts of water.

References: <sup>30</sup>

(a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

<sup>30</sup>See footnote 1, page 10.

Explosive D (Ammonium Picrate)

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- (b) D. P. MacDougall, Methods of Physical Testing, OGRD Report No. 803, 11 August 1942.
  - (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, OL Memo 10,303, 15 June 1949.
  - (d) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
  - (e) Various sources in the open literature.
  - (f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
340	1441	132	843	694	65	266	1737	328	1729
870	151	582		704	425	556	1797	838	1759
1390		1172		874	1585	796		1838	
		1352		1234	1655	986			
		1372		1724	1725	1466			
		1492			1885	1796			
					1895				

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Glycerol Monolactate Trinitrate (GLTN) Liquid

<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>9</sub> N <sub>3</sub> O <sub>11</sub> ) 299
C 24.1	O NO <sub>2</sub>
H 3.0	CH <sub>2</sub> - O - C - CH - CH <sub>3</sub>
N 14.1	CH - NO <sub>2</sub>
O 58.8	CH <sub>2</sub> - NO <sub>2</sub>
C/H Ratio	0.180
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 15 (1 lb wt); 42 Sample Wt 20 mg	<b>Boiling Point:</b> °C
Picatinny Arsenal Apparatus, in. Sample Wt, mg	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>20</sup> 1.464 n <sub>D</sub> <sup>25</sup>
<b>Friction Panel Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 5.9 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Shock Test:</b> Shock, gm 13.1
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 223 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None	<b>Trend Test, % TNT:</b>
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> %	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 28	

Glycerol Monolactate Trinitrate (GLTN) Liquid

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<p><b>Fragmentation Test:</b> <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<b>Shaped Charge Effectiveness, TNT = 100:</b>	
	Glass Cones	Steel Cones
	Hole Volume	
	Hole Depth	
	<b>Color:</b>	
	<b>Principal Use:</b> Gelatinizer for nitrocellulose	
	<b>Method of Loading:</b>	
	<b>Loading Density:</b> gm/cc	
	<b>Storage:</b>	
	Method	Liquid
<b>Hazard Class (Quantity-Distance)</b>		Class 9
<b>Compatibility Group</b>		
<b>Exudation</b>		
<b>Hydrolysis, % Acid:</b>		
10 days at 22°C		0.021
5 days at 60°C		0.014
<b>Solubility in Water,</b> <b>gm/100 gm, at:</b>		
25°C		< 0.01
60°C		< 0.015
<b>Solubility, gm/100 gm,</b> <b>at 25°C, in:</b>		
Ether		-
2:1 Ether:Alcohol		-
Acetone		-
<b>Heat of:</b>		
Combustion, cal/gm		2407

Preparation:

Glycerol monolactate (GML) is prepared by heating a glycerol lactic acid mixture containing 4% excess lactic acid at 116°C for 112 hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of 40/60 HNO<sub>3</sub>/H<sub>2</sub>SO<sub>4</sub>, maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from GML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below 100°C (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference:<sup>31</sup>

- (a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, PATR No. 1616, 22 July 1946.

<sup>31</sup>See footnote 1, page 10.

Glycol Dinitrate (GDN) Liquid

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<p><b>Composition:</b> %</p> <table style="margin-left: auto; margin-right: auto;"> <tr><td>C</td><td>15.8</td><td>ONO<sub>2</sub></td></tr> <tr><td>H</td><td>2.6</td><td>CH<sub>2</sub></td></tr> <tr><td>N</td><td>16.4</td><td>CH<sub>2</sub></td></tr> <tr><td>O</td><td>63.2</td><td>ONO<sub>2</sub></td></tr> <tr><td colspan="2">C/H Ratio 0.092</td><td></td></tr> </table>	C	15.8	ONO <sub>2</sub>	H	2.6	CH <sub>2</sub>	N	16.4	CH <sub>2</sub>	O	63.2	ONO <sub>2</sub>	C/H Ratio 0.092			<b>Molecular Weight:</b> (C <sub>2</sub> H <sub>4</sub> N <sub>2</sub> O <sub>6</sub> ) 152
C	15.8	ONO <sub>2</sub>														
H	2.6	CH <sub>2</sub>														
N	16.4	CH <sub>2</sub>														
O	63.2	ONO <sub>2</sub>														
C/H Ratio 0.092																
<b>Oxygen Balance:</b> CO <sub>2</sub> % 0.0 CO % 21																
<b>Density:</b> gm/cc    Liquid, 25°C 1.48																
<b>Melting Point:</b> °C -20																
<b>Freezing Point:</b> °C																
<b>Boiling Point:</b> °C																
<p><b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 4 (1 lb wt); 56 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg</p>	<b>Refactive Index:</b> n <sub>D<sup>20</sup></sub> n <sub>D<sup>20</sup></sub> 1.4452 n <sub>D<sup>20</sup></sub>															
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C															
<p><b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe</p> <p><b>Rifle Bullet Impact Test:</b> Trials %</p> <table style="margin-left: auto; margin-right: auto;"> <tr><td>Explosions</td><td></td></tr> <tr><td>Partials</td><td></td></tr> <tr><td>Burned</td><td></td></tr> <tr><td>Unaffected</td><td></td></tr> </table>	Explosions		Partials		Burned		Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm							
Explosions																
Partials																
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<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl																
<b>Ballistic Mortar, % TNT:</b>																
<b>Treitz Test, % TNT:</b>																
<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT																
<p><b>75°C International Heat Test:</b> % Loss in 48 Hrs</p> <p><b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs</p>	<b>Detonation Rate:</b> Confinement Glass tube Condition Liquid Charge Diameter, in. 10 Density, gm/cc 1.485 Rate, meters/second 7300 and 2050															
	<b>Flammability Index:</b>															
	<b>Hygroscopicity:</b> % 30°C, 90% RH 0.00															
<b>Volatility:</b>																

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Glycol Dinitrate (GDN) Liquid

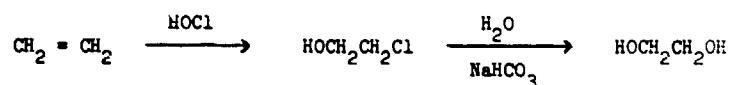
<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th><th>Steel Cones</th></tr> </thead> <tbody> <tr> <td>Hole Volume</td><td></td></tr> <tr> <td>Hole Depth</td><td></td></tr> </tbody> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth																							
Glass Cones	Steel Cones																												
Hole Volume																													
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<p><b>Color:</b> Yellow</p>																													
<p><b>Principal Uses:</b> Ingredient of nonfreezing dynamite</p>																													
<p><b>Method of Loading:</b></p>																													
<p><b>Loading Density:</b> gm/cc</p>																													
<p><b>Storage:</b></p> <table> <tr> <td>Method</td><td>Liquid</td></tr> </table>	Method	Liquid																											
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<p><b>Air:</b></p> <table> <tr> <td>Peak Pressure</td><td></td></tr> <tr> <td>Impulse</td><td></td></tr> <tr> <td>Energy</td><td></td></tr> </table> <p><b>Air, Confined:</b></p> <table> <tr> <td>Impulse</td><td></td></tr> </table> <p><b>Under Water:</b></p> <table> <tr> <td>Peak Pressure</td><td></td></tr> <tr> <td>Impulse</td><td></td></tr> <tr> <td>Energy</td><td></td></tr> </table> <p><b>Underground:</b></p> <table> <tr> <td>Peak Pressure</td><td></td></tr> <tr> <td>Impulse</td><td></td></tr> <tr> <td>Energy</td><td></td></tr> </table>	Peak Pressure		Impulse		Energy		Impulse		Peak Pressure		Impulse		Energy		Peak Pressure		Impulse		Energy										
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<p><b>Solubility in 1000 cc Water:</b></p> <table> <thead> <tr> <th>Temp, °C</th><th>Grams</th></tr> </thead> <tbody> <tr> <td>15</td><td>6.2</td></tr> <tr> <td>20</td><td>6.8</td></tr> <tr> <td>50</td><td>9.2</td></tr> </tbody> </table> <p><b>Viscosity, centipoises:</b></p> <table> <thead> <tr> <th>Temp, 20°C</th><th>4.2</th></tr> </thead> </table> <p><b>Vapor Pressure:</b></p> <table> <thead> <tr> <th>°C</th><th>mm Mercury</th></tr> </thead> <tbody> <tr> <td>0</td><td>0.0044</td></tr> <tr> <td>20</td><td>0.038</td></tr> <tr> <td>40</td><td>0.26</td></tr> <tr> <td>60</td><td>1.3</td></tr> <tr> <td>80</td><td>5.9</td></tr> <tr> <td>100</td><td>22.0</td></tr> </tbody> </table> <p><b>Heat of:</b></p> <table> <tr> <td>Combustion, cal/gm</td><td>1764</td></tr> <tr> <td>Formation, cal/gm (b)</td><td>366</td></tr> </table>		Temp, °C	Grams	15	6.2	20	6.8	50	9.2	Temp, 20°C	4.2	°C	mm Mercury	0	0.0044	20	0.038	40	0.26	60	1.3	80	5.9	100	22.0	Combustion, cal/gm	1764	Formation, cal/gm (b)	366
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Combustion, cal/gm	1764																												
Formation, cal/gm (b)	366																												

Glycol Dinitrate (GDN) Liquid

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Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethylglycol) may be prepared by nitration of ethylene glycol, HOCH<sub>2</sub>CH<sub>2</sub>OH, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:



Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was made of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mémo poudre 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

References:<sup>32</sup>

- (a) Ph. Macum, Nitroglycerin and Nitroglycerin Explosives, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.
- (b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).
- (c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, 34, 296 (1927).
- (d) Wm. H. Rinkenbach, Application of the Vacuum Stability Test to Nitroglycerin and Nitroglycerin Explosives, PATR 1524, 27 August 1946.

<sup>32</sup>See footnote 1, page 10.

<b>Composition:</b>		<b>Molecular Weight:</b>	93
%			
RDX	45		
TNT	30	Oxygen Balance:	
Aluminum	20	CO <sub>2</sub> %	-66
D-2 Wax	5	CO %	-36
Calcium Chloride, added	0.5	<b>Density:</b> gm/cc	Cast 1.74
C/H Ratio		<b>Melting Point:</b> °C	
k -act Sensitivity, 2 Kg Wt:		<b>Freezing Point:</b> °C	
Bureau of Mines Apparatus, cm	--	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		<b>Refractive Index,</b> n <sub>20</sub> <sup>o</sup>	
Picatinny Arsenal Apparatus, in. (c)	14	n <sub>25</sub> <sup>o</sup>	
Sample Wt, mg	18	n <sub>30</sub> <sup>o</sup>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	---	90°C	----
<b>Rifle Bullet Impact Test:</b>	Trials (b)	100°C	0.47
Explosions	%	120°C	
Partials	80	135°C	
Burned	--	150°C	
Unaffected	20	<b>200 Gram Bomb Sand Test:</b>	
<b>Explosion Temperature:</b>	°C (a)	Sand, gm	49.5
Seconds, 0.1 (no CCP used)	---	<b>Sensitivity to Initiation:</b>	
1	---	Minimum Detonating Charge, gm	
5	610(min) (c)	Mercury Fulminate	----
10		Lod Azide	0.20
15		Tetryl	0.10
20		<b>Ballistic Mortar, % TNT:</b> (d)	135
<b>75°C International Heat Test:</b>	% Loss in 48 Hrs	<b>Troux Test, % TNT:</b>	
<b>100°C Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss, 1st 48 Hrs	0.78	Method	
% Loss, 2nd 48 Hrs	0.00	Condition	
Explosion in 100 Hrs	None	Confined	
<b>Flammability Index:</b>		Density, gm/cc	
<b>Hygroscopicity:</b> %	30°C, 95% RH, 7 days	Brisance, % TNT	
	71°C, 95% RH, 7 days		
<b>Volatility:</b>		<b>Detonation Rate:</b>	(a, b)
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.71
		Rate, meters/second	7191

<b>Booster Sensitivity Test:</b> Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc		<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec) Heat, kilocalories/mole (ΔH, kcal/mol) Temperature Range, °C Phase
<b>Heat of:</b> Combustion, cal/gm 3972 Explosion, cal/gm 923 Gas Volume, cc/gm 733 Formation, cal/gm Fusion, cal/gm 78°C (b) 10.25		<b>Armor Plate Impact Test:</b>  <b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec Aluminum Fineness
<b>Specific Heat:</b> c, cal/gm °C (b) 30°C 0.269 50°C 0.268		<b>500-lb General Purpose Bomb:</b>  Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
<b>Burning Rate:</b> cm/sec		<b>Bomb Drop Test:</b>  <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b> Max Safe Drop, ft
<b>Thermal Conductivity:</b> (b) -3 cal/sec/cm/°C 35°C 1.10 x 10 <sup>-3</sup>		<b>500-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Coefficient of Expansion:</b> Linear, Δl/inch 0°C 4.0 x 10 <sup>-4</sup> 35°C 8.3 x 10 <sup>-4</sup> 70°C 13.1 x 10 <sup>-4</sup>		<b>1000-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Hardness, Mohs' Scale:</b>		
<b>Young's Modulus:</b> (b) E', dynes/cm <sup>2</sup> 9.0 x 10 <sup>9</sup> E, lb/inch <sup>2</sup> 1.30 x 10 <sup>5</sup> Density, gm/cc 1.71		
<b>Compressive Strength:</b> lb/inch <sup>2</sup> See below		
<b>Vapor Pressure:</b> °C mm Mercury		
<b>Compressive Strength:</b> lb/inch <sup>2</sup> 1083 Density, gm/cc 1.71 Ultimate deformation, % 1.32		

<b>Fragmentation Test:</b> (b)		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot EGS-1-17:		Gloss Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			
For Composition B	998	<b>Color:</b>	
For Subject HE	714	Gray	
For 80/20 Tritonal.	616	<b>Principal Uses:</b>	
3 inch HE, M42A1 Projectile, Lot KC-5:			HE charge
Density, gm/cc		<b>Method of Lending:</b>	
Charge Wt, lb		Cast	
<b>Total No. of Fragments:</b>			<b>Leading Density: gm/cc</b>
For TNT		1.71	
For Subject HE		<b>Storage:</b>	
<b>Fragment Velocity: ft/sec</b>			<b>Method</b>
At 9 ft		Dry	
At 25½ ft		<b>Hazard Class (Quantity-Distance):</b>	
Density, gm/cc		Class 9	
<b>Blast (Relative to TNT):</b> (a)			<b>Compatibility Group</b>
Air: 3.25" diameter sphere		Group I	
Peak Pressure Δ psi Catenary	25.4	<b>Exudation</b>	
Impulse NFOC Pendulum	19.8	None	
Energy	----		
<b>Air, Confined:</b>			
Impulse			
<b>Under Water:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Underground:</b>			
Peak Pressure			
Impulse			
Energy			

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity\*

(Reference e)

<u>Explosive</u>	<u>Simulated Altitude, Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
		<u>Confined m/s</u>	<u>Unconfined m/s</u>	<u>Confined m/s</u>	<u>Unconfined m/s</u>
TNT, density, gm/cc 1.59	Ground	6820	6720	6670	5270
	30,000	6660	6930(2)	6610	6760(4)
	60,000	6800	-	6520	6400(4)
	90,000	6810	6720	6550	6610(1)
Average		6798	6790	6588	6260
B-6, density, gm/cc 1.69	Ground	7190	7360	7340	6870
	30,000	7300(2)	7430	7360	7980
	60,000	7280	7490	7550	7010
	90,000	7300(3)	7270	7500	7000
Average		7268	7385	7438	7215

\*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes\* (e)

<u>Explosive</u>	<u>Charge Diameter, Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground m/s</u>	<u>30,000 m/s</u>	<u>60,000 m/s</u>	<u>90,000 m/s</u>
TNT, density, gm/cc 1.51	1	2940	2991	3119	2868
	2	3623	4191	5077	4980
B-6, density, gm/cc 1.71	1	3461	3405	3467	3563
	2	4603	4726	4998	5288

\*Outside diameter 2.54"; inside diameter 2.04"; length 7".

References:

See HMX-1; HMX-3 reference list.

AMCP 706-177

Haleite (Ethylene Dinitramine) (EDNA)

(In recognition of its development as a military explosive by the late Dr. G. C. Hale of Picatinny Arsenal.)

<b>Composition:</b> %	$\text{H}_2\text{C}-\text{N}(\text{NO}_2)_2-\text{H}$	<b>Molecular Weight:</b> $(\text{C}_2\text{H}_6\text{N}_2\text{O}_4)$ 150
C 16.0		<b>Oxygen Balance:</b>
H 4.0		CO: % -32
N 37.3		CO % -10.5
O 42.7		<b>Density:</b> gm/cc Crystal 1.71
C/H Ratio 0.066		<b>Melting Point:</b> °C Decomposes 175+
		<b>Freezing Point:</b> °C
		<b>Boiling Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Refractive Index, <math>n_{20}^D</math></b>
Bureau of Mines Apparatus, cm	48	$n_{25}^D$
Sample Wt 20 mg		$n_{30}^D$
Picatinny Arsenal Apparatus, in.	14	
Sample Wt, mg	17	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>
Steel Shoe	Unaffected	cc/40 Hrs, at
Fiber Shoe	Unaffected	90°C
		100°C 0.5
<b>Rifle Bullet Impact Test:</b>	Trials	120°C 1.5
Explosions	%	135°C --
Partials	0	150°C 11+
Burned	60	
Unaffected	20	
		<b>200 Gram Bomb Sand Test:</b>
<b>Explosion Temperature:</b>	°C	Sand, gm 52.3
Seconds, 0.1 (no cap used)	265	
1	216	<b>Sensitivity to Initiation:</b>
5 Decomposes	189	Minimum Detonating Charge, gm
10	178	Mercury Fulminate 0.21
15	173	Lead Azide 0.13
20	170	Tetryl --
<b>75°C International Heat Test:</b>		<b>Ballistic Mortar, % TNT:</b> (a) 139
% Loss in 48 Hrs	0.01	<b>Trouxi Test, % TNT:</b> (b) 122
<b>150°C Heat Test:</b>		<b>Plate Dent Test:</b> (c)
% Loss, 1st 48 Hrs	0.2	Method A
% Loss, 2nd 48 Hrs	0.3	Condition Pressed
Explosion in 100 Hrs	None	Confined Yes
		Density, gm/cc 1.50
<b>Flexibility Index:</b>	138	Brisance, % TNT 122
<b>Hygroscopicity:</b> %	0.01	<b>Detonation Rate:</b>
		Confinement Unconfined
<b>Volatility:</b>	Nil	Condition Pressed
		Charge Diameter, in. 1.0
		Density, gm/cc 1.49
		Rate, meters/second 7570

Haleite (Ethylene Dinitroethane) (EDNA)

AMCP 706-177

<b>Booster Sensitivity Test:</b>	(d) Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(e) Pressed 100 2.09 1.42	Decomposition Equation: (e) Oxygen, atoms/sec $10^{12.8}$ $10^{12.1}$ $10^{11.1}$ (Z/sec) Heat, kilocalorie/mole    30.5    37.3    30.8 ( $\Delta H$ , kcal/mcl) Temperature Range, °C    184-254    --    144-164 Phase                      Liquid    Solid    Solid
<b>Heat of:</b>	Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	2477 1276 908 134	<b>Armor Plate Impact Test:</b>  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness
<b>Specific Heat:</b> cal/gm/°C			<b>500-lb General Purpose Bomb:</b>  Plate Thickness, inches  1 1½ 1½ 1¾
<b>Burning Rate:</b> cm/sec			<b>Bomb Drop Test:</b>  <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>  Max Safe Drop, ft
<b>Thermal Conductivity:</b> cal/sec/cm/°C			<b>500-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Coefficient of Expansion:</b> Linear, %/°C			<b>1000-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Volume, %/°C</b>			
<b>Hardness, Mohs' Scale:</b>			
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc			
<b>Compressive Strength:</b> lb/inch <sup>2</sup>			
<b>Vapor Pressure:</b> °C                      mm Mercury			

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Haleite (Bthylen Dinitramine) (EDNA)

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	1.61		
Charge Wt, lb	--	Hole Volume	
Total No. of Fragments:		Hole Depth	
For TNT			
For Subject HE			
3 inch HE, M42A1 Projectile, Lot KC-5:			
Density, gm/cc			
Charge Wt, lb			
Total No. of Fragments:			
For TNT		Method of Loading:	
For Subject HE		Pressed	
Fragment Velocity: ft/sec		Loading Density: gm/cc      psi x 10 <sup>3</sup>	
At 9 ft		5      10      12      15      20	
At 25½ ft		1.28      1.38      1.41      1.44      1.49	
Density, gm/cc		Storage:	
Blow (Relative to TNT):		Method	
Air:		Dry	
Peak Pressure		Hazard Class (Quantity-Distance)	
Impulse		Class 9	
Energy		Compatibility Group	
Air, Confined:			
Impulse		Exudation	
Under Water:		None	
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			

Haleite (Ethylene Dinitramine) (EDNA)

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Compatibility with Metals:

Dry - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acid-proof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Magnesium and magnesium-aluminum alloy are slightly affected.

Wet - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:Bureau of Mines Impact Test, 2 Kg Wt:

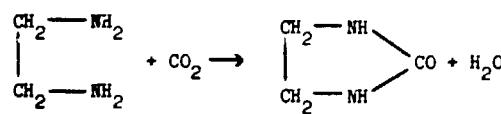
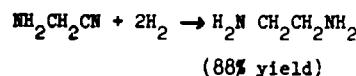
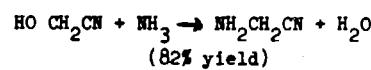
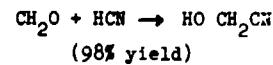
<u>Habit</u>	<u>cm</u>
1st plate	55
2nd plate	55
Bi-pyramid	71
Bracydome	66
Sphenoid	46

Solubility: gm/100 gm (%) of:

<u>Water</u>		<u>Alcohol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	0.25	20	1.00
40	0.75	40	2.46
60	2.13	60	5.22
80	6.36	78	10.4
100	>20		

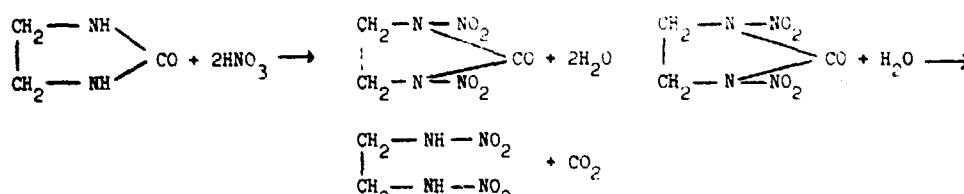
Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)



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Haleite (Ethylene Dinitramine) (EDNA)



The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220°C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chloroethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N'-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethylenurea is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethylenurea produced appears to hydrolyze, yielding Haleite, immediately after solution in water at 95°C. Both the nitration and hydrolysis are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klotbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and ethylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

References:<sup>33</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Report AC-2983/Org Ex 179.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (f) M. A. Cook and M. Taylor Abegg, "Isothermal Decomposition of Explosives." University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

<sup>33</sup>See footnote 1, page 10.

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Haleite (Ethylene Dinitramine) (EDNA)

(e) Also see the following Picatinny Arsenal Technical Reports on Haleite:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1200	1231	1162	1113	414	1255	786	897	1198	1279
1290	1451	1232	1493	1294	1325	1796	1737	1288	1319
1360	1651	1252	1923	1434	1395		1797	1378	1379
1380		1352			1885		1937	1388	1469
1400		1372						1838	1489
1600									2179

<b>Composition:</b>		<b>Molecular Weight:</b>	102
%			
RDX	40	Oxygen Balance:	-68
TNT	38	CO <sub>2</sub> %	-35
Aluminum	17	CO %	
D-2 Wax	5	<b>Density:</b> gm/cc	Cast 1.72
Calcium Chloride, added	0.5	<b>Melting Point:</b> °C	
C/H Ratio		<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point:</b> °C	
Bureau of Mines Apparatus, cm	--	<b>Refractive Index, n<sub>d20</sub>:</b>	
Sample Wt 20 mg		n <sub>d20</sub>	
Picatinny Arsenal Apparatus, in.	16	n <sub>d20</sub>	
Sample Wt, mg	21	n <sub>d20</sub>	
<b>Friction Pendulum Test: (b)</b>		<b>Vacuum Stability Test:</b>	(a, b)
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	---	90°C	----
<b>Rifle Bullet Impact Test:</b>	Trials (b)	100°C	0.47
Explosions	%	120°C	0.98
Partials	73	135°C	----
Burned	--	150°C	11+
Unaffected	28	<b>200 Gram Bomb Sand Test:</b>	
<b>Explosion Temperature:</b>	°C (a)	Sand, gm	48.1
Seconds, 0.1 (no cap used)	---	<b>Sensitivity to Initiation:</b>	
1	---	Minimum Detonating Charge, gm	
5	480	Mercury Fulminate	----
10		Lead Azide	0.20
15		Tetryl	0.10
20		<b>Ballistic Mortar, % TNT:</b>	(d) 133
<b>75°C Intrinsic at Test:</b>		<b>Treuzl Test, % TNT:</b>	
% Loss in 48		<b>Plate Dent Test:</b>	
<b>100°C Heat Test:</b>	(b)	Method	
% Loss, 1st 48 Hrs	0.058	Condition	
% Loss, 2nd 48 Hrs	0.00	Confined	
Explosion in 100 Hrs	None	Density, gm/cc	
<b>Flammability Index:</b>		Brisance, % TNT	
<b>Hygroscopicity:</b> % 30°C, 95% RH, 7 days	2.98	<b>Detonation Rate:</b>	(a, b)
7°C, 95% RH, 7 days	1.13	Confinement	None
<b>Volatility:</b>		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.69
		Rate, meters/second	7224

<b>Booster Sensitivity Test:</b>		(c)	<b>Decomposition Equation:</b>
Condition	Cast		Oxygen, atoms/sec (Z/sec)
Tetryl, gm	100		Heat, kilocalorie/mole (ΔH, kcal/mol)
Wax, in. for 50% Detonation	1.25		Temperature Range, °C
Wax, gm			Phase
Density, gm/cc	1.73		
<b>Heat of:</b>		(b)	<b>Armor Plate Impact Test:</b>
Combustion, cal/gm	3882		60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec
Explosion, cal/gm	919		Aluminum Fineness
Gas Volume, cc/gm			
Formation, cal/gm	758		<b>500-lb General Purpose Bomb:</b>
Fusion, cal/gm 78°C	9.25		Plate Thickness, inches
<b>Specific Heat: cal/gm/°C</b>		(b)	
30°C	0.249		1
50°C	0.264		1½
			1¾
<b>Burning Rate:</b>			
cm/sec			
<b>Thermal Conductivity:</b>		(b)	<b>Bomb Drop Test:</b>
cal/sec/cm/°C 35°C	0.97 x 10 <sup>-3</sup>		<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>
<b>Coefficient of Expansion:</b>			Max Safe Drop, ft
Linear, ΔL/inch			
0°C	46 x 10 <sup>-4</sup>		<b>500-lb General Purpose Bomb vs Concrete:</b>
35°C	95 x 10 <sup>-4</sup>		Height, ft
70°C	159 x 10 <sup>-4</sup>		Trials
<b>Hardness, Mohs' Scale:</b>			Unaffected
			Low Order
<b>Young's Modulus:</b>		(b)	High Order
E', dynes/cm <sup>2</sup>	10.3 x 10 <sup>9</sup>		<b>1000-lb General Purpose Bomb vs Concrete:</b>
E, lb/inch <sup>2</sup>	1.49 x 10 <sup>5</sup>		Height, ft
Density, gm/cc	1.69		Trials
<b>Compressive Strength: lb/inch<sup>2</sup></b>		See below	Unaffected
<b>Vapor Pressure:</b>			Low Order
°C mm Mercury			High Order
Compressive Strength: lb/inch <sup>2</sup>	1303		
Density, gm/cc	1.69		
Ultimate deformation, %	1.3%		

<b>Fragmentation Test:</b> (b)		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot EGS-1-17:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
Total No. of Fragments:			
For Composition B	998	Color:	Gray
For Subject HE	910	Principal Uses:	HE charge
For 80/20 Tritonal	616		
3 inch HE, M42A1 Projectile, Lot KC-5:			
Density, gm/cc		Method of Loading:	Cast
Charge Wt, lb		Loading Density: gm/cc	1.69
Total No. of Fragments:			
For TNT		Storage:	
For Subject HE		Method	Dry
Fragment Velocity: ft/sec		Hazard Class (Quantity-Distance)	Class 9
At 9 ft		Compatibility Group	Group I
At 25½ ft		Exudation	None
Density, gm/cc			
<b>Blast (Relative to TNT):</b> (a)			
Air: 3.25" diameter sphere			
Peak Pressure A psi Catenary	24.7		
Impulse	NPOC Pendulum	19.6	
Energy		-----	
Air, Confined:			
Impulse			
Under Water:			
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			

<b>Composition:</b>	<b>Molecular Weight:</b> 64	
%		
RDX	31	Oxygen Balance:
TNT	29	CO <sub>2</sub> % -75
Aluminum	35	CO % 49
D-2 Wax	5	<b>Density:</b> gm/cc Cast 1.84
Calcium Chloride, added	0.5	<b>Melting Point:</b> °C
C/H Ratio		<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b>		
Bureau of Mines Apparatus, cm	--	<b>Boiling Point:</b> °C
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	15	<b>Refractive Index, n<sub>d20</sub>:</b>
Sample Wt, mg	23	n <sub>d20</sub> n <sub>d25</sub> n <sub>d30</sub>
<b>Friction Pendulum Test:</b>		
Steel Shoe	Unaffected	<b>Vacuum Stability Test:</b> (a, b)
Fiber Shoe	---	cc/40 Hrs, at 90°C ---- 100°C 0.45 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b>	Trials	(b)
Explosions	78	<b>200 Gram Bomb Sand Test:</b> (b) Sand, gm 44.9
Partials	--	
Burned	--	
Unaffected	22	
<b>Explosion Temperature:</b>	°C (a)	<b>Sensitivity to Initiation:</b>
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm
1	---	Mercury Fulminate ----
5	500	Lead Azide 0.20
10		Tetryl 0.10
15		
20		
<b>75°C International Heat Test:</b>		
% Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b> (d) 111
<b>107°C Heat Test:</b>	(b)	<b>Trexel Test, % TNT:</b>
% Loss, 1st 48 Hrs	0.70	
% Loss, 2nd 48 Hrs	0.00	<b>Plate Dent Test:</b>
Explosion in 100 Hrs	None	Method
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> %	30°C, 95% RH, 7 days	Condition
(b)	0.01	Confinement
	71°C, 95% RH, 7 days	Cast
	0.31	Charge Diameter, in.
<b>Volatility:</b>		
		1.0
		Density, gm/cc 1.81
		Rate, meters/second 6917

<b>Booster Sensitivity Test:</b>		<b>Decomposition Equation:</b>
Condition		Oxygen, atoms/sec (Z/sec)
Tetryl, gm		Heat, kilocalorie/mole ( $\Delta H$ , kcal/mol)
Wax, in. for 50% Detonation		Temperature Range, °C
Wax, gm		Phase
Density, gm/cc		
<b>Heat of:</b>	(b) 4495	
Combustion, cal/gm		
Explosion, cal/gm		877
Gas Volume, cc/gm		
Formation, cal/gm		491
Fusion, cal/gm		9.30
<b>Specific Heat: cal/gm/°C</b>		
30°C	0.254	
50°C	0.254	
<b>Burning Rate:</b>		
cm/sec		
<b>Thermal Conductivity:</b>	(b) $1.70 \times 10^{-3}$	
cal/sec/cm/°C 35°C		
<b>Coefficient of Expansion:</b>	(b) $4.0 \times 10^{-4}$	
Linear, $\Delta L/L$ /inch		
0°C		
35°C		$8.3 \times 10^{-4}$
70°C		$13.0 \times 10^{-4}$
<b>Hardness, Mohs' Scale:</b>		
<b>Young's Modulus:</b>	(b) $11.5 \times 10^9$	
E', dynes/cm <sup>2</sup>		
E, lb/inch <sup>2</sup>		$1.67 \times 10^5$
Density, gm/cc		1.81
<b>Compressive Strength: lb/inch<sup>2</sup></b>	See below	
<b>Vapor Pressure:</b>		
°C mm Mercury		
Compressive Strength: lb/inch <sup>2</sup>	1610	
Density, gm/cc	1.31	
Ultimate deformation, %	1.37	

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot EGS-1-17:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
Total No. of Fragments:		Color:	
For Composition B	998		Grey
For Subject HE	476		
Fw 80/20 Tritonal	616	Principal Uses:	
3 inch HE, M42A1 Projectile, Lot KC-5:		HE charge	
Density, gm/cc		Method of Loading:	
Charge Wt, lb		Cast	
Total No. of Fragments:		Loading Density: gm/cc	
For TNT		1.81	
For Subject HE		Storage:	
Fragment Velocity: ft/sec		Method	
At 9 ft		Dry	
At 25½ ft		Hazard Class (Quantity-Distance)	
Density, gm/cc		Class 9	
Blast (Relative to TNT): (a)		Compatibility Group	
Air: 3.25" diameter sphere		Group I	
Peak Pressure Δ psi Catenary	25.5	Exudation	
Impulse NFOC Pendulum	20.6	None	
Energy	----		
Air, Confined:			
Impulse			
Under Water:			
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			

The Stability of HBX Compositions Made With and  
Without Desiccants and Containing Added Moisture \*

Explosive Composition	Moisture, %	Acidity, %	100°C Vac Stab Test		Hygroscopicity, %	
			cc gas	Hours	30°C	71°C
<u>Standard HBX-1</u>	0.73	0.011	0.47	40	+2.98	+1.13
+0.2% moisture			0.68	40		
+0.4% moisture			0.62	40		
+0.6% moisture			0.50	40		
<u>HBX-1 without CaCl<sub>2</sub></u>	0.00	0.029	0.36	40	-0.06	-0.25
+0.2% moisture			0.25	40		
+0.4% moisture			0.23	40		
+0.6% moisture			0.27	40		
<u>HBX-1 with silica gel</u>	0.06	0.031	0.73	40	+0.08	+0.04
<u>Standard HBX-3</u>	0.54	0.012	0.45	40	+2.01	+0.31
+0.2% moisture			0.47	40		
+0.4% moisture			0.43	40		
+0.6% moisture			0.41	40		
<u>HBX-3 without CaCl<sub>2</sub></u>	0.02	0.049	0.46	40	-0.06	-0.29
+0.2% moisture			0.26	40		
+0.4% moisture			0.26	40		
+0.6% moisture			0.20	40		
<u>HBX-3 with silica gel</u>	0.04	0.100	0.45	40	+0.09	+0.05
<u>Standard H-6</u>	0.71	0.017	0.47	40	+2.01	+1.77
+0.2% moisture			0.88	40		
+0.4% moisture			0.63	40		
+0.6% moisture			0.65	40		
<u>H-6 without CaCl<sub>2</sub></u>	0.03	0.082	0.10	40	-0.06	-0.25
+0.2% moisture			0.10	40		
+0.4% moisture			0.25	40		
+0.6% moisture			0.23	40		
<u>H-6 with silica gel</u>	0.05	0.028	0.43	40	+0.09	+0.06

\* All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Scientific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

HBX-1; HBX-3Preparation:

HBX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet RDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 84% paraffin and other waxes, 14% nitrocellulose and 2% lecithin. The mixture is cooled from approximately 95° to 100°C to a temperature considered suitable for casting (the lowest practicable pour temperature). HBX can also be made by adding the calculated amount of TNT to Composition B to obtain the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Torox II, for high blast explosive applications.

References:<sup>34</sup>

- (a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PATR No. 2353, November 1956.
- (b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo. 10,303, 15 June 1949.
- (d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, NAVORD Report No. 1502, 26 July 1950.
- (e) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DA-19-020-501-ORD-(P)-58).

i) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

<sup>34</sup>See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b>	47.6
Potassium Perchlorate (17 microns)	32	Oxygen Balance: CO <sub>2</sub> %	-42
Aluminum, atomized (20 microns)	48	CO %	-34
RDX (through 325 mesh)	16	Density, gm/cc, Apparent Pressed at 20,000 psi	1.39 2.1
Asphaltum (through 100 mesh)	4	Melting Point: °C	
C/H Ratio		Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	--	Boiling Point: °C	
Sample Wt 20 mg		Refractive Index, n <sub>d20</sub> n <sub>d25</sub> n <sub>d30</sub>	
Picatinny Arsenal Apparatus, in.	16	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Sample Wt, mg	24	90°C	----
Friction Pendulum Test:		100°C	1.25
Steel Shoe	Detonates	120°C	
Fiber Shoe	Unaffected	135°C	
<b>Rifle Bullet Impact Test:</b> Trials	%	150°C	
Explosions		<b>200 Gram Bomb Sand Test:</b> Sand, gm	12.5
Partials		<b>Sensitivity to Initiation:</b> Minin... Detonating Charge, gm	
Burned		Mercury Fulminate	----
Unaffected		Lead Azide	0.20
Expllosion Temperature: °C		Tetryl	0.25
Seconds, 0.1 sec (if used)	---	<b>Ballistic Mortar, % TNT:</b>	
1	---	<b>Trouxl Test, % TNT:</b>	
5	520	<b>Plot, Dent Test:</b> Method	
10		Condition	
15		Confined	
20		Density, gm/cc	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		Brisance, % TNT	
<b>100°C Heat Test:</b>		<b>Detonation Rate:</b>	
% Loss, 1st 48 Hrs	0.15	Confinement	
% Loss, 2nd 48 Hrs	0.00	Condition	
Explosion in 100 Hrs	None	Charge Diameter, in.	
<b>Flammability Index:</b>		Density, gm/cc	
<b>Hygroscopicity:</b> %	None	Rate, meters/second	
<b>Volatility:</b>	None		

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Gray	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot XC-5:</b>		<b>Principal Uses:</b> HE filler for small caliber projectiles	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT		Pressed	
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		Pressed at 20,000 psi	2.1
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
		Method	Dry
<b>Blast (Relative to TNT):</b>		<b>Hazard Class (Quantity-Distance)</b>	
<b>Air:</b>		<b>Compatibility Group</b>	
Peak Pressure			
Impulse			
Energy		Exudation	None
<b>Air, Confined:</b>		<b>Static Tests:</b>	
Impulse		<b>20 mm T215E1 Projectile:</b>	
<b>Under Water:</b>		PA Peak Pressure, psi	55
Peak Pressure		NFOC 20" Blast Cube	44
Impulse		APG 24" Blast Cube	44
Energy		<b>Static Tests:</b>	
<b>Underground:</b>		<b>20 mm M97 Projectile:</b>	
Peak Pressure		HEX-24	Tritonal
Impulse		Foxboro psi	Torpex
Energy		19	12.4
<b>Flame Temperature, °K</b>	2552	Catenary psi	13.0
<b>Activation Energy, kcal</b>	20.4	46	----
Temp, °C	450 to 570	Duration, microsec	----
Specific reaction rate, k	$1.64 \times 10^{-5}$	APG 24" Blast Cube	36
		24	32
<b>Heat of:</b>		<b>Combustion, cal/gm</b>	
		Explosion, cal/gm	4197
		Gas volume, cc/gm	1858
			159

<b>Composition:</b>		<b>Molecular Weight:</b>	47.6
%			
Potassium Perchlorate (17 microns)	32	Oxygen Balance:	
Aluminum, flaked (1 micron)	48	CO, %	-42
RDX (through 325 mesh)	16	CO %	-34
Asphaltum (through 100 mesh)	4	Density: gm/cc Apparent Pressed at 20,000 psi	0.69 1.62
C/H Ratio		Melting Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		Freezing Point: °C	
Bureau of Mines Apparatus, cm		Boiling Point: °C	
Sample Wt 20 mg		Refractive Index, $n_{20}^D$	
Picatinny Arsenal Apparatus, in.		$n_{25}^D$	
Sample Wt, mg		$n_{30}^D$	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Partially detonates	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
<b>Rifle Bullet Impact Test:</b>	Trials	100°C	1.52
Explosions	%	120°C	
Partials		135°C	
Burned		150°C	
Unaffected		<b>200 Gram Bomb Sand Test:</b>	
<b>Explosion Temperature:</b>	°C	Sand, gm	23.7
Seconds, 0.1 (no cap used)	---	<b>Sensitivity to Initiation:</b>	
1	---	Minimum Detonating Charge, gm	
5	545	Mercury Fulminate	----
10		Lead Azide	0.20
15		Tetryl	0.25
20		<b>Ballistic Mortar, % TNT:</b>	
<b>75°C International Heat Test:</b>		<b>Trouxl Test, % TNT:</b>	
% Loss in 48 Hrs		<b>Plate Dent Test:</b>	
<b>100°C Heat Test:</b>		Method	
% Loss, 1st 48 Hrs		Condition	
% Loss, 2nd 48 Hrs		Confined	
Explosion in 100 Hrs		Density, gm/cc	
<b>Flammability Index:</b>		Brisance, % TNT	
<b>Hygroscopicity:</b> %		<b>Detonation Rate:</b>	
<b>Volatility:</b>		Confinement	
		Condition	
		Charge Diameter, in	
		Density, gm/cc	
		Rate, meters/second	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>		
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones      Steel Cones		
Density, gm/cc		Hole Volume		
Charge Wt, lb		Hole Depth		
<b>Total No. of Fragments:</b>		<b>Color:</b>		
For TNT		Gray		
For Subject HE		<b>Principal Uses:</b> HE filler for small caliber projectiles		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>				
Density, gm/cc				
Charge Wt, lb				
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>		
For TNT		Pressed		
For Subject HE				
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>		
At 9 ft		Pressed at 20,000		
At 25½ ft		1.62		
Density, gm/cc				
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>		
<b>Air:</b>		Method		
Peak Pressure		Dry		
Impulse				
Energy		<b>Hazard Class (Quantity-Distance)</b>		
<b>Air, Confined:</b>		<b>Compatibility Group</b>		
Impulse				
<b>Under Water:</b>		<b>Exudation</b>		
Peak Pressure		None		
Impulse				
Energy				
<b>Underground:</b>		<b>Static Tests:</b>		
Peak Pressure		<u>20 mm T215E1 Projectile:</u>		
Impulse		PA Peak Pressure, psi		
Energy		77		
		NFOC 20" Blast Cube		
		45		
		APG 24" Blast Cube		
		42		
		<b>Static Tests:</b>		
		<u>20 mm M97 Projectile:</u>		
		HEX-46		
Flame temperature, °K		TNT		
Activation energy, kcal		Tetryl		
Temp. °C		Fostoro psi		
Heat of f.		17.3		
Explosion, cal/gm		2.8		
Exp. Volume, cubic cm		3.5		
Rate of reaction, sec⁻¹		Catenary psi		
Rate, k		43		
		28		
		Duration, microsec		
		517		
		560		
		APG 24" Blast Cube		
		---		
		10		

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HEX-48

Cook-Off Tests: (c)

20 mm T215E1 HEX-48 Loaded Projectiles With Dye-Coated RDX Top-Off

Projectile No.	Cut-Off Temp. °C	Cook-Off
1	170	Yes (198)
2	150	No
3	155	Yes (190)
4	150 to 175	No

National Northern Projectile Load:

MOX-2B (no top-off)	195
MOX-2B (Tetryl top-off)	150
MOX-2B (97/3, RDX/wax top-off)	175
MOX-2 (no top-off)	175

Fragment Penetration Tests: (c)

Projectile	Filler	Altitude, Feet	Avg. No. of Penetrations per Round in Zone 65°-130°		
			0.020"	0.040"	0.051"
T215E1	PRX-48	Ground	352	264	282
		60,000	676	432	388
T282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EX8 Mod 0	MOX-2B	Ground	476	268	224
		60,000	672	264	256

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward 0° and the base toward 180°.

The test data indicate that on the thicker panels, 0.040" and 0.051," the HEX-48 loaded T215E1 projectile produced more complete fragment penetrations at ground and altitude than MOX-2B loaded T282E1 and EX8 Mod 0 projectiles.

HEX-24; HEX-48Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

An alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtain a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high energy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high blast compositions suitable for use in small caliber projectiles.

References:<sup>35</sup>

- (a) O. E. Sheffield and E. J. Murray, Development of Explosives-Metallized Explosives-High Blast Fillers for Small Caliber Shell, Picatinny Arsenal Memorandum Report No. MR-49, 21 December 1953.
- (b) O. E. Sheffield, Properties of MOX-Type Explosive Mixtures, PATR No. 2205, October 1955.
- (c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 1951.

<sup>35</sup>See footnote 1, page 10.

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2,4,4',2',4",6"-Hexanitro-oxanilide (HNO)

<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>14</sub> H <sub>12</sub> N <sub>2</sub> O <sub>14</sub> )
C 33.0	
H 1.2	
N 21.9	
O 43.9	
C/H Ratio 0.797	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg	<b>Oxygen Balance:</b> CO <sub>2</sub> % -53.4 CO % -9.4
Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 12	<b>Density:</b> gm/cc
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Melting Point:</b> °C Decomposes 302
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>Freezing Point:</b> °C
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 384 10 15 20	<b>Boiling Point:</b> °C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Refractive Index:</b> n <sub>20</sub> n <sub>25</sub> n <sub>30</sub>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C 0.40
<b>Flammability Index:</b>	<b>200 Gram Bomb Sand Test:</b> Sand, gm 52.1
<b>Hygroscopicity:</b> % 25°C, 90% RH 0.17	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.30 Tetryl 0.25
<b>Volatility:</b>	<b>Ballistic Mortar, % TNT:</b>
	<b>Trauzl Test, % TNT:</b>
	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in Density, gm/cc Rate, meters/second

2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

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<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A<sup>1</sup> Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  <table><thead><tr><th>Glass Cones</th><th>Steel Cones</th></tr></thead><tbody><tr><td>Hole Volume</td><td></td></tr><tr><td>Hole Depth</td><td></td></tr></tbody></table> <b>Color:</b> Almost white  <b>Principal Uses:</b> Igniter powder; pyrotechnic compositions  <b>Method of Loading:</b> Pressed and extruded  <b>Loading Density:</b> gm/cc  <b>Storage:</b> Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation None	Glass Cones	Steel Cones	Hole Volume		Hole Depth	
Glass Cones	Steel Cones						
Hole Volume							
Hole Depth							

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2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

Solubility in the following substances:

<u>Solvent</u>	
Nitrobenzene	<3 gm in 100 cc, at 23°C ~ 5 gm in 100 cc, at 210°C
Water	0.10 gm in 100 cc, at 100°C
Alcohol (Ethyl)	Insoluble
Acetone	Insoluble
Benzene	Insoluble
Butyl acetate	Insoluble
Carbon tetrachloride	Insoluble
Dimethylformamide	Very soluble
Ether (Ethyl)	Insoluble
Acetic Acid	Insoluble
Nitric Acid	Soluble
Crystalline form	Long rectangular glistening plates from nitrobenzene

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxanilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxanilide (HNO) "slurry" is filtered on a Führer funnel and purified as explained under "Tetranitro-oxanilide."

Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc 61, 462 (1892)).

References: 36

- (a) L. Gowen and R. Dwiggins, Case Gun Ignition Studies, NAVORD Report No. 2321, 13 June 1952.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro OXanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF1-83, 20 December 1954.
- (c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136,330, 11 April 1951.
- (d) S. Livingston, Development of Improved Ignition Type Powders, PATT No. 2267, July 1956.

<sup>36</sup>See footnote 1, page 10.

beta-HMX (a)

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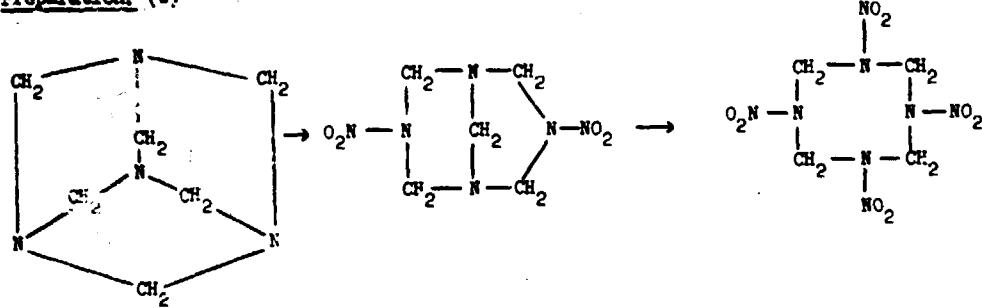
<b>Composition:</b> %		<b>Molecular Weight:</b> (C <sub>4</sub> H <sub>8</sub> N <sub>2</sub> O <sub>8</sub> ) 296
C 16.2	O <sub>2</sub> N-N <sub>2</sub>	<b>Oxygen Balance:</b>
H 2.7	CH <sub>2</sub>	CO <sub>2</sub> % -21.6
N 37.9	H <sub>2</sub> C	CO % 0.0
O 43.2	O <sub>2</sub> N-N <sub>2</sub>	<b>Density:</b> gm/cc      Crystal 1.90
C/H Ratio 0.095	CH <sub>2</sub>	<b>Melting Point:</b> °C Capillary method 273 Kofler Micro Hot Stage 260
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Freezing Point:</b> °C
Bureau of Mines Apparatus, cm	32	<b>Boiling Point:</b> °C
Sample Wt 20 mg		<b>Refractive Index:</b> n <sub>D</sub> <sub>20</sub>
Picatinny Arsenal Apparatus, in.	9	n <sub>D</sub> <sub>20</sub>
Sample Wt, mg	23	n <sub>D</sub> <sub>20</sub>
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>
Steel Shoe	Explodes	cc/40 min at
Fiber Shoe	Unaffected	90°C
		100°C 0.37
<b>Rifle Bullet Impact Test:</b> Trials	%	120°C 0.45
Explosions		135°C --
Partial		150°C 0.62
Burned		<b>200 Gram Bomb Sand Test:</b>
Unaffected		Sand, gm 60.4
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>
Seconds, 0.1 (no cap used)	380	Minimum Detonating Charge, gm
1	--	Mercury Fulminate
5	327	Lead Azide 0.30
10	306	Tetryl
15	--	<b>Ballistic Mortar, % TNT:</b> 150
20	--	<b>Trend Test, % TNT:</b> 145
<b>75°C Intermediate Heat Test:</b>		<b>Plate Dent Test:</b>
% Loss in 48 Hrs		Method
<b>100°C Heat Test:</b>		Condition
% Loss, 1st 48 Hrs	0.05	Confined
% Loss, 2nd 48 Hrs	0.03	Density, gm/cc
Explosion in 100 Hrs	None	Brisant, % TNT
<b>Kommodity Index:</b>		<b>Detonation Rate:</b>
<b>Hygroscopicity:</b> % 30°C, 95% RH	(c) 0.00	Confinement
<b>Volatility:</b>		Condition
		Charge Diameter, in.
		Density, gm/cc 1.64
		Rate, meters/second 9124

<b>Buster Sensitivity Test:</b>		
Condition		(e) 9.7
Tetryl, gm		$10^{-1}$
Wax, in. for 50% Detonation		
Wax, gm		52.7
Density, gm/cc		271-314
<b>Heat of:</b>		
Combustion, cal/gm	23t.	
Explosion, cal/gm (e)	1356	
Gas Volume, cc/gm		
Formation, cal/gm (e)	-60.5	
Fusion, cal/gm		
<b>Specific Heat: cal/gm/°C</b>		
	Recrystallized	(g)
°C	°C	
-75	0.153	85
0	0.228	90
25	0.243	100
50	0.266	125
75	0.282	150
<b>Burning Rate:</b>		
cm/sec		
<b>Thermal Conductivity:</b>		
cal/sec/cm/°C		
<b>Coefficient of Expansion:</b>		
Linear, %/°C		
Volume, %/°C		
<b>Harden, Mohs' Scale:</b> (e) 2.3		
<b>Young's Modulus:</b>		
E', dynes/cm <sup>2</sup>		
E, lb./inch <sup>2</sup>		
Density, gm/cc		
<b>Compressive Strength: lb/inch<sup>2</sup></b>		
Vapor Pressure:		
°C	mm Mercury	
<b>Decomposition Equation:</b>		
Oxygen, atoms/sec		
(Z/sec)		
Heat, kilocalories/mole		
(ΔH, kcal/mol)		
Temperature Range, °C		
Phase		Liquid
<b>Armor Plate Impact Test:</b>		
60 mm Master Projectile:		
50% Inert, Velocity, ft/sec		
Aluminum Fineness		
<b>500-lb General Purpose Bomb:</b>		
Plate Thickness, inches		
1		
1½		
1¾		
2		
<b>Bomb Drop Test:</b>		
T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:		
Max Safe Drop, ft		
<b>500-lb General Purpose Bomb vs Concrete:</b>		
Height, ft		
Trials		
Unaffected		
Low Order		
High Order		
T625-1b General Purpose Bomb vs Concrete:		
Height, ft		
Trials		
Unaffected		
Low Order		
High Order		

beta-HMX

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Preparation: (b)



Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one man can complete the procedure. A 1-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five cc of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to  $45 \pm 1^\circ C$ , and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride and 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-HMX precipitate (yield 73% HMX).

The RDX is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N NaOH added at the rate of 3 cc/min. When about 730 cc have been added the pH increases sharply from a little over 8.7 to over 9.7 which corresponds to complete destruction of the RDX. Filter the HMX from the hot mixture; yield 612 gm, mp 279.5°-280.5°. Recrystallization from nitromethane yields material melting at 281°-282°.

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form RDX. It is now manufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from HMX-RDX Mixtures and Recovery of a RDX-HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMX containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-HMX-acetone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steam bath and while boiling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decanted. The residual HMX is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetone extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

Pure HMX obtained -	353.9 gm	70.78%
Total RDX-HMX mixture recovered -		
137.5 gm		26.5%
Samples taken during process -		
2.4 gm		0.48%
Loss during process		<u>2.2%</u>
Total		100.00%

Various samples were analyzed for RDX content:

1. Crude HMX	12.25% RDX
2. After first acetone washing	6.0% RDX
3. After second acetone washing	2.0% RDX
4. After third acetone washing	0.0% RDX
RDX-HMX sample recovered	54.5% RDX

Preparation of Fine Particle-size HMX by the Aspirator Method:

1. Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide.
2. Filter the HMX solution.
3. Connect a clean aspirator to the water line.
4. Place a 55 gallon clean drum under the aspirator.
5. Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMX-dimethyl sulfoxide container, to the side intake of the aspirator.
6. Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.
7. Open the water faucet and then place the polyethylene tube in the HMX container.
8. White milky fine HMX separates out in the drum. Total duration of run is approximately 7 minutes.
9. After all the HMX solution is sucked out of the container, the water is turned off.
10. The material is filtered and water washed.
11. If dry HMX is required, the material can be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

1. Filter the combined hot acetone extracts.
2. Pour while agitating the filtered extracts into at least 4 times its volume of water.
3. Filter and dry, etc.

beta-HMX

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Color:

White

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I (dry) Group M (wet)
Emulsion	None

References:<sup>37</sup>

- (a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-Txl-23, 7 April 1952.
- (b) W. E. Backmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.
- (c) S. Livingston, Characteristics of Explosives HMX and DFBN, PATR No. 1561, 6 September 1945.
- (d) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (e) O. H. Johnson, HMX as a Military Explosive, NAVORD Report No. 4371, 1 October 1956.
- (f) Also see the following Picatinny Arsenal Technical Reports on HMX:

1	2	6	1	2
1741	2183	2016	1737	1709 2059

- (g) C. Lenhart, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

<sup>37</sup>See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b>	91
HMX	49	Oxygen Balance:	
TNT	29	CO <sub>2</sub> %	-5%
Aluminum	22	CO %	-27%
C/H Ratio		<b>Density:</b> gm/cc	Cast 1.90
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	--	<b>Melting Point:</b> °C	
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
Picatinny Arsenal Apparatus, in.	17	<b>Solidus Point:</b> °C	
Sample Wt, mg	25	<b>Refractive Index,</b> n <sub>20</sub>	
<b>Friction Pendulum Test:</b>		n <sub>25</sub>	
Steel Shoe	Unaffected	n <sub>30</sub>	
Fiber Shoe	Unaffected	n <sub>35</sub>	
<b>Rifle Bullet Impact Test: 10 Trials, %</b>		<b>Vacuum Stability Test:</b>	
<u>3/16" Steel</u>	<u>1/8" Al</u>	cc/40 Hrs, at	
Explosions	30	90°C	----
Partials	--	100°C	----
Burned	10	120°C	0.37
Unaffected	0	135°C	
		150°C	
<b>Explosion Temperature:</b>	°C	<b>200 Gram Bomb Sand Test:</b>	
Seconds, 0.1 (no cap used)	---	Sand, gm	61.3
1	---	<b>Sensitivity to Initiation:</b>	
5 Flames erratically	370	Minimum Detonating Charge, gm	
10		Mercury Fulminate	----
15		Lod Azide	0.30
20		Tetryl	-----
<b>75°C International Heat Test:</b>		<b>Ballistic Mortar, % TNT:</b>	120
% Loss in 48 Hrs		<b>Tread Test, % TNT:</b>	
<b>100°C Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss, 1st 48 Hrs		Method	
% Loss, 2nd 48 Hrs		Condition	
Explosion in 100 Hrs		Confined	
<b>Flammability Index:</b>		Density, gm/cc	
<b>Hygroscopicity:</b> %		Brisance, % TNT	
<b>Volatility:</b>		<b>Deceleration Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.90
		Rate, meters/second	7866

<b>Burner Sensitivity Test:</b>		<b>Decomposition Equation:</b>
Condition		Oxygen, atoms/sec (Z/sec)
Tetryl, gm		Heat, kilocalorie/mole (ΔH, kcs./mol)
Wax, In. for 50% Detonation		Temperature Range, °C
Wax, gm		Phase
Density, gm/cc		
<b>Heat of:</b>		<b>Armor Plate Impact Test:</b>
Combustion, cal/gm	3687	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec
Explos. Ion, cal/gm	1190	Aluminum Fineness
Gas Volume, cc/gm	680	
Formation, cal/gm	----	<b>500-lb General Purpose Bomb:</b>
Fusion, cal/gm		Plate Thickness, inches
<b>Specific Heat: cal/gm/°C</b>		1
32° to 74°C	0.245	1½
		1¾
		2
<b>Burning Rate:</b>		
cm/sec		
<b>Thermal Conductivity:</b>		<b>Bomb Drop Test:</b>
cal/sec/cm/°C		<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>
<b>Coefficient of Expansion:</b>		Max Safe Drop, ft
Linear, %/°C		
<b>Volume, %/°C</b>		<b>500-lb General Purpose Bomb vs Concrete:</b>
<b>Hardness, Moh. Scale:</b>		Height, ft
		Trials
<b>Young's Modulus:</b>		Unaffected
E', dynes/cm²		Low Order
E, lb/inch²		High Order
Density, gm/cc		<b>1000-lb General Purpose Bomb vs Concrete:</b>
<b>Compressive Strength: lb/inch²</b>	2260	Height, ft
	See below	Trials
<b>Vapor Pressure:</b>		Unaffected
°C	mm Mercury	Low Order
Compressive Strength: lb/inch²	*	High Order
Average (10 tests)	2260	
High	2530	<b>Ultimate Deformation: %</b>
Low	1910	Average (10 tests) 2.81
		High 3.22
		Low 2.52

\* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Gloss Cones</b>	<b>Steel Cones</b>
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			<b>Criter:</b>
For TNT			Gray
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> HE projectile and bomb filler	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>			<b>Method of Leaching:</b>
For TNT			Cast
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Leaching Density: gm/cc</b>	
At 9 ft		1.90	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air		Method	Dry
Peak Pressure		Hazard Class (Quantity-Distance)	Class 9
Impulse		Compatibility Group	Group I
Energy		Exudation	None
<b>Air, Confined:</b>		<b>Work to Produce Rupture: ft-lb/inch<sup>3</sup> *</b>	
Impulse		Average (10 tests)	2.77
		High	3.39
		Low	2.40
<b>Under Water:</b>		<b>Diffusion Viscosity, Saybolt Seconds:</b>	
Peak Pressure		24.8	
Impulse			
Energy			
<b>Underground:</b>		<b>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</b>	
Peak Pressure			
Impulse			
Energy			

HTA-3Modulus of Elasticity: \*

lb/inch <sup>2</sup>	
Average	89,200
High	97,400
Low	76,300

\* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	119,000 psi *
Density, gm/cc	1.92

\* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References:<sup>38</sup>

(a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."

(b) R. Brown and R. Velicky, Heat Capacity of HTA-3, Picatinny Arsenal General Laboratory Report No. 58-HI-509, 5 May 1958.

<sup>38</sup>See footnote 1, page 10.

Lead Azide

<b>Composition:</b> %			<b>Molecular Weight:</b> $(PbN_6)$ 291
N 26.8			Oxygen Balance: C 2% -5.5 Cl 1% -5.0
Pb 71.2			Density: gm/cc      Crystal 4.80 Dextrinized 4.38
C/H Ratio			Melting Point: °C      Decomposes
Impact Sensitivity, 2 Kg Wt: Pure <u>Dextrinized</u>			Frosting Point: °C
Bureau of Mines Apparatus, cm 10	17		Boiling Point: °C
Sample Wt 20 mg			Refractive Index, $n_{D}^{20}$
Picatinny Arsenal Apparatus, in. 3	5		$n_{D}^{20}$
Sample Wt, mg	30	28	$n_{D}^{20}$
Friction Pendulum Test:			Vacuum Stability Test: <u>Dextrinized</u>
Steel Shoe      Explodes			cc/40 Hrs, at
Fiber Shoe      Explodes			90°C
Rifle Bullet Impact Test: Trials %			100°C      1.0
Explosions			120°C      0.07
Partials			135°C
Burned			150°C
Unaffected			200 Gram Bomb Shock Test:
Explosion Temperature: °C			Sand, gm      Black powder fuse 19.
Seconds, 0.1 (no cap used) 390			Sensitivity to Initiators:
1 356			Minimum Detonating Charge, gm
5 Explodes 340			Mercury Fulminate
10 335			Lead Azide
15 335			Tetryl
20 335			Ballistic Mortar, % TNT:
75°C International Heat Test: % Loss in 48 Hrs			Treitz Test, % TNT: (a) 39
100°C Heat Test:			Plate Dent Test:
% Loss, 1st 48 Hrs 0.34			Method
% Loss, 2nd 48 Hrs 0.05			Condition
Explosion in 100 Hrs None			Confined
Flammability Index:			Density, gm/cc
Hygrosopicity: % <u>Dextrinized</u> Not Dextrinized			Brisance, % TNT
30°C, 90% RH 0.8 0.03			Detonation Rate: <u>Pure Lead Azide</u>
Volatility:			Confinement
			Condition      Pressed
			Charge Diameter, in.
			Density, gm/cc      2.0      3.0      4.0
			Rate, meters/second      4070      4630      5180

Lead Azide

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<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc		<b>Shaped Charge Effectiveness: TNT = 100:</b> <table border="1"> <thead> <tr> <th>Gloss Cone</th> <th>Matte Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <table border="1"> <tr> <td>Color:</td> <td>White-buff</td> </tr> </table> <b>Principal Uses:</b> Detonators, priming compositions, and commercial blasting caps	Gloss Cone	Matte Cones	Hole Volume		Hole Depth		Color:	White-buff		
Gloss Cone	Matte Cones											
Hole Volume												
Hole Depth												
Color:	White-buff											
<b>Stress (Relative to TNT):</b> Air: Peak Pressure Impulse Energy  Air, Confined: Impulse  Under Water: Peak Pressure Impulse Energy  Underground: Peak Pressure Impulse Energy <b>Heat of:</b> Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm		<b>Method of Loading:</b> Pressed  <table border="1"> <tr> <td>Loading Density: gm/cc</td> <td>psi <math>\times 10^3</math></td> </tr> <tr> <td>3</td> <td>5</td> <td>10</td> <td>15</td> </tr> <tr> <td>2.62</td> <td>2.71</td> <td>2.96</td> <td>3.07</td> </tr> </table> <b>Storage:</b> Method: Wet  <b>Hazard Class (Quantity-Distance):</b> Class 9  <b>Compatibility Group:</b> Group M (wet)  <b>Exudation:</b> None  <b>Compatibility with Metals:</b> Dry lead azide does not react with or corrode steel, iron, nickel, aluminum, lead, zinc, copper, tin or calcium. It does not affect coatings of acid-proof black paint, oil, NRC compound or shellac. Lead azide in the presence of moisture corrodes zinc and copper; and with copper, it forms the extremely sensitive and dangerous copper azide.	Loading Density: gm/cc	psi $\times 10^3$	3	5	10	15	2.62	2.71	2.96	3.07
Loading Density: gm/cc	psi $\times 10^3$											
3	5	10	15									
2.62	2.71	2.96	3.07									
630 367 308 -346		<b>Specific Heat: cal/gm/<math>^{\circ}</math>C</b> <table border="1"> <thead> <tr> <th><math>^{\circ}</math>C</th> <th></th> </tr> </thead> <tbody> <tr> <td>-50</td> <td>0.110</td> </tr> <tr> <td>0</td> <td>0.110</td> </tr> <tr> <td>25</td> <td>0.110</td> </tr> <tr> <td>50</td> <td>0.110</td> </tr> </tbody> </table> <b>Thermal Conductivity:</b> cal/sec/cm/ $^{\circ}$ C (Pure) $1.55 \times 10^{-4}$	$^{\circ}$ C		-50	0.110	0	0.110	25	0.110	50	0.110
$^{\circ}$ C												
-50	0.110											
0	0.110											
25	0.110											
50	0.110											

Compatibility with Metals:

Dry: Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead azide at ambient temperature and 50°C. Monel, chrome-nickel and Inconel were unaffected under the same conditions in two and one-half years.

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide (1% moisture) after 20 months' exposure at ambient temperature and 50°C, and J-1 magnesium-aluminum alloy is very slightly corroded.

<u>Sample Tested</u>	<u>Lead Azide</u>	<u>Lead Azide</u> plus 25% Water	<u>Lead Azide</u> plus 20% Water	<u>Lead Azide</u> plus 20% Ethyl Alco- hol (95%)
	Dry			

Friction Pendulum Test:

(All IA dextrinized)

<u>Shoe</u>	<u>Fiber</u>	<u>Fiber</u>	<u>Steel</u>	<u>Fiber</u>	<u>Steel</u>	<u>Fiber</u>
No. of Trials	1	10	12	10	4	1
Explosions	1	0	0	0	1	1
Creaklings		0	2	0	2	0
Unaffected	0	10	10	10	1	0

Impact Sensitivity, 2 Kg Wt:

(All IA dextrinized)

PA Apparatus, inches	4	9	9	4
----------------------	---	---	---	---

Activation Energy: (c)

Kcal/mole	23.74
Induction Period, seconds	0.5-10

Initiating Efficiency, Grams Required to Give Complete Initiations of:Dextrinized Azide (gm)

TNT	0.25
Tetryl	0.10
RDX	0.05
PETN	0.02

Sensitivity to Static Discharge, Joules (Pure Lead Azide) (b)

0.0070

Lead Azide

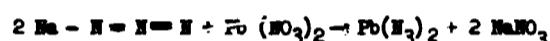
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Compatibility of Dextrinized Lead Azide with Black Powder:  
100°C Vacuum Stability Test, cc/40 hr:

<u>Sample Wt (gm)</u>	<u>Material</u>	<u>cc</u>
1.0	Lead Azide	0.50
1.0	Black Powder	0.38
2.0	50/50, Lead Azide/Black Powder	1.26

Solubility of Pure Lead Azide; gm/100 gm of Water:

<u>°C</u>	<u>g</u>
20	0.05

Preparation of Lead Azide (Dextrinized): (du Pont procedure)

Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lbs dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead azide is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium azide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperature in 12 minutes, and allowed to settle 10 minutes. The mother liquor is decanted and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronimus (French Patent 304,792) should be credited with the first attempt in 1907 to use lead azide with some success in the explosive industry. Its commercial manufacture started in Europe before World War II and in the United States since 1931 as military or commercial grade "dextrinized" lead azide.

Destruction by Chemical Decomposition:

Lead azide can be decomposed by

(1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supernatant solution of sodium azide and drain into the soil.

(2) dissolving in a 10% solution of ammonium acetate and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.

(3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium nitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

Lead Azide

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References: <sup>39</sup>

- (a) Ph. Naoum, Z ges Schiess Sprengstoffe, 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PAIR #222, November 1955.
- (d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

0	1	2	3	4	5	6	7	8	9
550	561	832	393	524	255	326	567	628	609
580	861	852	1393	784	525	856	637	708	719
600	1451	882	1493	824	1325	866	657	748	749
760	1651	932	2093	944	1485	1316	707	788	769
1450		1132	2133	2164		1486	1737	838	849
				2204		1556	2227	1388	999
		1152						1528	2179
		1352						1638	
		1372							2198

<sup>39</sup>See footnote 1, page 10.

Lead 2,4-Dinitroresorcinate (LDNR)

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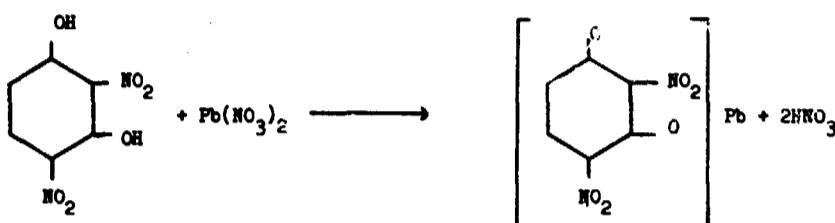
<b>Composition:</b> %			<b>Molecular Weight:</b> (PbC <sub>6</sub> H <sub>2</sub> N <sub>2</sub> O <sub>6</sub> ) 405
C 17.8		O —	
H 0.5		NO <sub>2</sub>	
N 6.9		O —	
O 23.7		Pb	
Pb 51.1			
C/H Ratio 0.549			
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 1 kg wt 30			
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.			
Sample Wt, mg 20			
<b>Friction Pendulum Test:</b> Steel Shoe			
Fiber Shoe			
<b>Rifle Bullet Impact Test:</b> Trials %			
Explosions			
Partials			
Burned			
Unaffected			
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)			
1			
5 Explodes	265		
10			
15			
20			
<b>75°C International Heat Test:</b> % Loss in 48 Hrs			
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.20			
% Loss, 2nd 48 Hrs 0.02			
Explosion in 100 Hrs None			
<b>Flammability Index:</b>			
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.73			
<b>Velocity:</b>			
<b>Oxygen Balance:</b> CO <sub>2</sub> % -32			
CO % -8			
<b>Density:</b> gm/cc Crystal 3.2			
<b>Melting Point:</b> °C			
<b>Freezing Point:</b> °C			
<b>Boiling Point:</b> °C			
<b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup>			
n <sub>D</sub> <sup>25</sup>			
n <sub>D</sub> <sup>28</sup>			
<b>Vacuum Stability Test:</b> cc/40 Hrs, at			
90°C			
100°C			
120°C (73 minutes) Explodes			
135°C			
150°C			
<b>200 Gram Bomb Sand Test:</b> Sand, gm Black powder fuse 20			
<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm			
Mercury Fulminate			
Lead Azide			
Tetryl			
<b>Ballistic Mortar, % TNT:</b>			
<b>Treesil Test, % TNT:</b>			
<b>Plate Disk:</b> Metric			
Condition			
Confined			
Density, gm/cc			
Brisance, % TNT			
<b>Detonation Rate:</b> Confinement			
Condition			
Charge Diameter, in.			
Density, gm/cc			
Rate, meters/second			

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  Color:                  Red or yellow  Principal Uses:        Electric detonators  Method of Loading:     Pressed  Loading Density: gm/cc  Storage: Method                  Wet Hazard Class (Quantity-Distance)    Class 9 Compatibility Group Exudation                None	
<b>Blast (Relative to TNT):</b>  Air: Peak Pressure Impulse Energy  Air, Confined: Impulse  Under Water: Peak Pressure Impulse Energy  Underground: Peak Pressure Impulse Energy		<u>Initiating Efficiency:</u> 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi.  <u>Heat of:</u> Explosion, cal/gm      270	

Lead 2,4-Dinitroresorcinate (LDMR)

AMCP 706-177

Preparation:



To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium carbonate in 500 cc of boiling water is added slowly a solution of 10 grams of lead nitrate dissolved in 60 cc of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cool to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol and ether. It is dried in a steam oven.

Origin:

2,4-dinitroresorcin was described in the 1881 edition of Beilstein (Beil VII, 885). The same compound was described in more detail by Weselsky, Benedikt and Rübl in 1882 (M II, 323). The lead salt of 2,4-dinitroresorcinol appears to have been prepared between World War I and World War II by treating resorcinol with nitrous acid and oxidizing the resulting dinitroresorcinol to dinitroresorcinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresorcinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Popper, PATR No. 480, March 1934). The LDMR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

References:<sup>40</sup>

- (a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

0	3	4	8	9
480	453	1004	1328	859
580			1448	1079

<sup>40</sup>See footnote 1, page 10.

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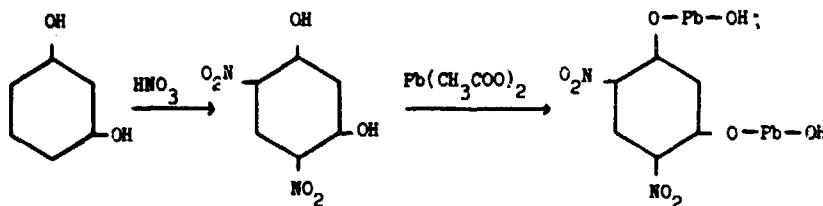
Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

<b>Composition:</b> %		<b>Molecular Weight:</b> (Pb <sub>2</sub> C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>8</sub> ) 646
C 11.2 H 0.6 N 4.3 O 19.8 Pb 64.1	O — Pb — OH O <sub>2</sub> N — C — NO <sub>2</sub> C/H Ratio 0.177	<b>Oxygen Balance:</b> CO <sub>2</sub> % -20 CO % -5
		<b>Density:</b> gm/cc
		<b>Melting Point:</b> °C 213
		<b>Freezing Point:</b> °C
		<b>Boiling Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 1 kg wt 60 Picatinny Arsenal Apparatus, in. Sample Wt, mg 20		<b>Refractive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>25</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		<b>Vacuum Stability Test:</b> cc./40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected		<b>200 Gram Bomb Shock Test:</b> Sand, on Bitter powder fuse 15
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Explodes 295 10 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		<b>Trend Test, % TNT:</b>
<b>Flammability Index:</b>		<b>Plate Dent Test:</b> Method Condition Confined
<b>Hygroscopicity:</b> %		Density, gm/cc Brisance, % TNT
<b>Vaporility:</b>		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

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<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  <b>Color:</b> Red or yellow  <b>Principal Uses:</b> Electric detonators  <b>Method of Loading:</b> Pressed  <b>Loading Density:</b> gm/cc  <b>Storage:</b> Method      Wet Hazard Class (Quantity-Distance)      Class 9 Compatibility Group Exudation      None  <u>Initiating Efficiency:</u> 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 psi.
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Preparation:

(a) One hundred grams of pure resorcinol is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C, 40 grams of the granulated resorcinol is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcinol is introduced, the mixture is further cooled to minus 50°C, and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight 43.6 grams. The crude 4,6-DNR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 340 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 98 percent sulphuric acid in 150 cc of water. The resulting precipitate of 4,6-DNR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).

(b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decantation three times with 100 cc portions of distilled water, and used immediately for the next operation.

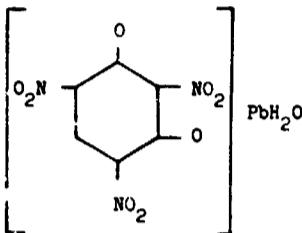
(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C, the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C. The basic lead 4,6-DNR is washed once by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

Origin:

Both the 2,4- and 4,6-dinitroresorcinol were described in some detail by Weselsky, Benedikt and Hüel in 1882 (M II, 323). Typle prepared the 4,6-dinitroresorcinol in 1883 by hydrolyzing the nitration product of resorcinol diacetate (Ber 16, 551). A more direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21a, "Manufacture of 4,6-Dinitroresorcinol and Lead 4,6-Dinitroresorcinol"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcinol and allowing the product in slurry to react with an excess of lead hydroxide at 90°C. This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATR 1448, September 1944).

Lead Styphnate

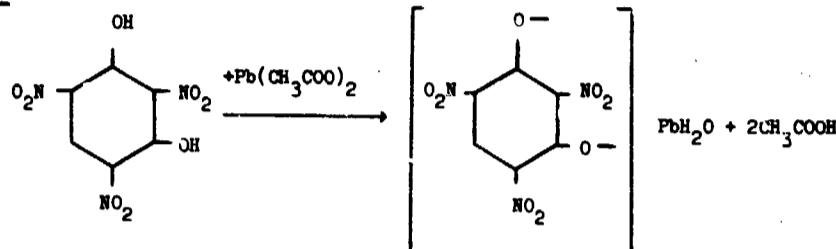
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<b>Composition:</b> %		<b>Molecular Weight:</b> (PbC6H3N3O9) 468
C 15.4 H 0.6 N 9.0 O 30.8 Pb 44.2		<b>Oxygen Balance:</b> CO <sub>2</sub> % -19 CO % 2
C/H Ratio 0.320		<b>Density:</b> gm/cc <b>Crystal</b> 3.02
		<b>Melting Point:</b> °C <b>Explodes</b> 260-310
		<b>Freezing Point:</b> °C
		<b>Boiling Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 17 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) 8 Sample Wt, mg 22		<b>Refractive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>20</sup>
<b>Friction Pendulum Test:</b> Steel Shoe      Detonates Fiber Shoe      Detonates		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.4 120°C 0.3 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials % Explosives Partials Burned Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm      24 Black powder fuse      11.1
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Explodes 282 10 276 15 272 20 267		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate      Trace* Lead Azide      Trace* * <.001 gm, alternative
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.38 % Loss, 2nd 48 Hrs 0.73 Explosion in 100 Hrs None		<b>Treuzi Test, % TNT:</b> (a) 40
<b>Flammability Index:</b>		<b>Pile Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> % 25°C, 100% RH 0.05 30°C, 90% RH 0.02		<b>Detonation Rate:</b> Confinement Condition Charge Diameter Density, gm/cc 2.9 Rate, meters/second 5200
<b>Volatility:</b>		

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			<b>Color:</b> Orange-reddish brown
For TNT			
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-8:</b>		<b>Principal Uses:</b> Igniting charge, and ingredient of priming compositions	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Pressed	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Method	Wet
Peak Pressure			
Impulse		Hazard Class (Quantity-Distance)	Class 9
Energy			
Air, Confined:		Compatibility Group	Group M (wet)
Impulse			
Under Water:		Exudation	None
Peak Pressure			
Impulse			
Energy			
Underground:		<b>Activation Energy:</b>	
Peak Pressure		kcal/mol	75.39
Impulse		Induction Period, sec	0.5-10
Energy			
<u>Heat of:</u>		<u>Specific Heat: cal/cm/<sup>o</sup>C</u>	(c)
Combustion, cal/gm	1251	<u><sup>o</sup>C</u>	
Explosion, cal/gm	457	-50	0.141
Gas Volume, cc/gm	368	0	0.158
Formation, cal/gm	-92	25	0.164
		50	0.167

Lead Styphnate

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Preparation:

Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic acid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium carbonate in 80 cc distilled water. Add the lead acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at 70°-75°C and continue stirring for 3 hours at this temperature. Cool to 20°C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

Sensitivity to Static Discharge, joules: (b) 0.0009

Loss in Weight at 105°C: %

3 hours	0.02
6 hours	0.23
9 hours	0.23

Effect of Storage for 2 Months at 30°C, on:

Explosion Temperature Test Value	Nil
Sand Test Value	Nil
Sensitivity to Initiation	Nil

Solubility, gm/100 gm (%):

<u>Glycol Diacetate</u>	
<u>°C</u>	<u>%</u>
20-25	0.1

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw 34, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasen (Russia) 2, 81-5 (1935)).

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Lead Styphnate

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% sodium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References:<sup>41</sup>

- (a) Report AC-936/Org Rx 74.
- (b) F. W. Brown, D. H. Kunkel and F. C. Gibon, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3652, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.
- (d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

0	1	2	3	4	5	6	7	8	9
1450	11	1352	453	2164	1316	407	318	2179	
2220		2032	2093			1737			2077

<sup>41</sup>See footnote 1, page 10.

### Mannitol Hexanitrate (Nitromannite)

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<p><b>Composition:</b></p> <table style="margin-left: auto; margin-right: auto;"> <tr><td>%</td><td>CH<sub>2</sub>ONO<sub>2</sub></td></tr> <tr><td>C</td><td>O<sub>2</sub>KOCH</td></tr> <tr><td>H</td><td>O<sub>2</sub>NOCH</td></tr> <tr><td>N</td><td>HCONO<sub>2</sub></td></tr> <tr><td>O</td><td>HCONO<sub>2</sub></td></tr> <tr><td></td><td>CH<sub>2</sub>ONO<sub>2</sub></td></tr> <tr><td>C/H Ratio</td><td>0.133</td></tr> <tr><td></td><td></td></tr> <tr><td></td><td></td></tr> <tr><td></td><td></td></tr> </table>	%	CH <sub>2</sub> ONO <sub>2</sub>	C	O <sub>2</sub> KOCH	H	O <sub>2</sub> NOCH	N	HCONO <sub>2</sub>	O	HCONO <sub>2</sub>		CH <sub>2</sub> ONO <sub>2</sub>	C/H Ratio	0.133							<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>8</sub> N <sub>6</sub> O <sub>18</sub> ) 452
%	CH <sub>2</sub> ONO <sub>2</sub>																				
C	O <sub>2</sub> KOCH																				
H	O <sub>2</sub> NOCH																				
N	HCONO <sub>2</sub>																				
O	HCONO <sub>2</sub>																				
	CH <sub>2</sub> ONO <sub>2</sub>																				
C/H Ratio	0.133																				
<b>Oxygen Balance:</b>																					
CO <sub>2</sub> % 7.1																					
CO % 28.3																					
<b>Density:</b> gm/cc 1.73																					
<b>Melting Point:</b> °C 112-113																					
<b>Frosting Point:</b> °C																					
<b>Boiling Point:</b> °C Decomposes 150																					
<b>Refractive Index:</b> n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub> n <sub>D<sub>30</sub></sub>																					
<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C																					
<p><b>Friction Pendulum Test:</b></p> <table> <tr><td>Steel Shoe</td><td>Detonates</td></tr> <tr><td>Fiber Shoe</td><td>Unaffected</td></tr> <tr><td></td><td></td></tr> <tr><td><b>Rifle Bullet Impact Test:</b></td><td>Trials</td></tr> <tr><td></td><td>%</td></tr> <tr><td>Explosions</td><td></td></tr> <tr><td>Partials</td><td></td></tr> <tr><td>Burned</td><td></td></tr> <tr><td>Unaffected</td><td></td></tr> </table>	Steel Shoe	Detonates	Fiber Shoe	Unaffected			<b>Rifle Bullet Impact Test:</b>	Trials		%	Explosions		Partials		Burned		Unaffected		<b>200 Gram Pemb Sand Test:</b> Sond, µm 68.5		
Steel Shoe	Detonates																				
Fiber Shoe	Unaffected																				
<b>Rifle Bullet Impact Test:</b>	Trials																				
	%																				
Explosions																					
Partials																					
Burned																					
Unaffected																					
<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm																					
Mercury Fulminate --																					
Lead Azide 0.06																					
Tetryl --																					
<b>Ballistic Mortar, % TNT:</b>																					
<p><b>75°C International Heat Test:</b></p> <table> <tr><td>% Loss in 48 Hrs</td><td>0.4</td></tr> <tr><td></td><td></td></tr> <tr><td></td><td></td></tr> </table>	% Loss in 48 Hrs	0.4					<b>Trend Test, % TNT:</b> (c) 172														
% Loss in 48 Hrs	0.4																				
<b>Plate Dent Test:</b>																					
Method																					
<p><b>100°C Heat Test:</b></p> <table> <tr><td>% Loss, 1st 48 Hrs</td><td>--</td></tr> <tr><td>% Loss, 2nd 48 Hrs</td><td>--</td></tr> <tr><td>Explosion in 100 Hrs (Frothed)</td><td>48 hours</td></tr> <tr><td></td><td></td></tr> <tr><td></td><td></td></tr> <tr><td></td><td></td></tr> </table>	% Loss, 1st 48 Hrs	--	% Loss, 2nd 48 Hrs	--	Explosion in 100 Hrs (Frothed)	48 hours							Condition								
% Loss, 1st 48 Hrs	--																				
% Loss, 2nd 48 Hrs	--																				
Explosion in 100 Hrs (Frothed)	48 hours																				
Confined																					
Density, gm/cc																					
Brisance, % TNT																					
<b>Detonation Rate:</b> (d)																					
Confinement Yes																					
<p><b>Flammability Index:</b></p>	Condition Pressed																				
	Charge Diameter, in.																				
	Density, gm/cc																				
	Rate, meters/second																				
<p><b>Hygroscopicity:</b> % 30°C, 93% RH 0.17</p>	1.73																				
	82%																				
<b>Volatility:</b>																					

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <p><b>Color:</b></p> <p><b>Principal Uses:</b> Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j)</p>	Glass Cones	Steel Cones	Hole Volume		Hole Depth									
Glass Cones	Steel Cones														
Hole Volume															
Hole Depth															
<p><b>Fragment Velocity: ft/sec</b></p> <p>At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc</p>														
<p><b>Blast (Relative to TNT):</b></p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table border="1"> <thead> <tr> <th>Method</th> <th>Dry</th> </tr> </thead> <tbody> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> </tbody> </table> <p><b>Compatibility Group:</b></p> <p><b>Exudation:</b> None</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9										
Method	Dry														
Hazard Class (Quantity-Distance)	Class 9														
	<p><b>65.5°K I1 Test:</b></p> <table border="1"> <thead> <tr> <th>Minutes</th> <th>6</th> </tr> </thead> </table> <p><b>Heat of:</b> (e, f, g)</p> <table border="1"> <thead> <tr> <th>Combustion, cal/gm</th> <th>1515</th> <th>1525</th> </tr> </thead> <tbody> <tr> <td>Explosion, cal/gm</td> <td>1390</td> <td>1454</td> <td>1468</td> <td>1520</td> </tr> <tr> <td>Formation, cal/cm</td> <td>337</td> <td>345</td> <td>366</td> </tr> </tbody> </table>	Minutes	6	Combustion, cal/gm	1515	1525	Explosion, cal/gm	1390	1454	1468	1520	Formation, cal/cm	337	345	366
Minutes	6														
Combustion, cal/gm	1515	1525													
Explosion, cal/gm	1390	1454	1468	1520											
Formation, cal/cm	337	345	366												

Mannitol Hexanitrate (Nitromannite)

AMCP 706-177

Solubility:

- a. Insoluble in water.
- b. Slightly soluble in cold alcohol (2.9 gm at 13°C).
- c. Slightly soluble in ether (4 gm at 9°C).
- d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

- a. Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.
- b. Introduce in small portions, 10 gm of d-mannitol, while swirling the flask to break up any lumps of mannite which might form. Keep the temperature below 0°C.
- c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.
- d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.
- e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 16.2% N as determined by the nitrometer.)
- f. Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a water-heated funnel.
- g. Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.
- h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at 112°-113°C and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Origin:

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (Congr rend. 1847, 121). It is the hexanitric ester of d-mannitol which is widely distributed in nature, particularly in the plant Fraxinus ornus. N. Sokoloff, a Russian chemist, investigated the explosive properties of it and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Berthelot, Sarrazin and Vieille. Dumonte, Menard, Strecker, Tichanovich (Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Explosives," Industria Chimica 8, 1093-1102 (1933)).

References:<sup>42</sup>

- (a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

<sup>42</sup>See footnote 1, page 1C.

Mannitol Hexanitrate (Nitromannite)

- (b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detonating Compounds to Frictional Impact, Impact, and Heat," J. Frank Inst 204, 369-76 (1927).
  - (c) Ph. Macum, Z ges Schiess - Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
  - (d) H. Kast, Z angev Chem, 36, 74 (1923).
  - (e) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262, (1934).
  - (f) Landolt and Börnstein, E III, p. 2914.
  - (g) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Macum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, (1928), pp. 156, 247-250.
  - (h) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262 (1934) G. Fleury, L. Briessand and P. Ihoste, "Structure and Stability of Nitric Esters," Comp rend 224, 1016-18 (1947).
  - (i) W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.
  - (j) Sarran and Vielle, Mém poudr 2, 161 (1884-1889).
  - (k) L. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).
  - (l) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).
  - (m) B. T. Fedoroff, Handbook of Explosives and Related Items, Picatinny Arsenal (unpublished).
  - (n) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TM1-16, 23 January 1952.
  - (o) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:
- |      |    |    |   |
|------|----|----|---|
| 2    | 4  | 2  | 6 |
| 1352 | 24 | 85 | 6 |
|      | 64 |    |   |

Mercury Fulminate

AMCP 706-177

<p><b>Composition:</b> %</p> <table style="margin-left: 20px;"> <tr><td>C</td><td>8.4</td><td style="text-align: center;">O — N = C</td></tr> <tr><td>N</td><td>9.8</td><td style="text-align: center;">Hg</td></tr> <tr><td>O</td><td>11.2</td><td style="text-align: center;">O — N = C</td></tr> <tr><td>Hg</td><td>70.6</td><td></td></tr> <tr><td colspan="2">C/H Ratio</td><td></td></tr> </table>	C	8.4	O — N = C	N	9.8	Hg	O	11.2	O — N = C	Hg	70.6		C/H Ratio			<b>Molecular Weight:</b> (HgC <sub>2</sub> N <sub>2</sub> O <sub>2</sub> ) 285
C	8.4	O — N = C														
N	9.8	Hg														
O	11.2	O — N = C														
Hg	70.6															
C/H Ratio																
<b>Oxygen Balance:</b> CO <sub>2</sub> % -17 CO % .5																
<b>Density:</b> gm/cc <b>Crystal</b> 4.43																
<b>Melting Point:</b> °C <b>Decomposes</b>																
<b>Freezing Point:</b> °C																
<b>Boiling Point:</b> °C																
<p><b>Impact Sensitivity, 2 Kg Wt:</b>            Bureau of Mines Apparatus, cm 5; (1 kg wt) 35            Sample Wt 20 mg</p> <p>Picatinny Arsenal Apparatus, in. 2; (1 lb wt) 4            Sample Wt, mg 30</p>	<b>Ref refractive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>25</sup>															
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C															
	100°C <b>Explodes</b>															
	120°C															
<p><b>Friction Pendulum Test:</b>            Steel Shoe Explodes            Fiber Shoe Explodes</p> <p><b>Rifle Bullet Impact Test:</b> Trials %</p> <p>Explosions</p> <p>Partials</p> <p>Burned</p> <p>Unaffected</p>	135°C															
	150°C															
	<b>200 Gram Bomb Shock Test:</b> Shock, gm      Black powder fuse 23.4															
	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl															
<p><b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.18</p> <p><b>100°C Heat Test:</b> Exploded in 16 hours % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs</p>	<b>Ballistic Mortar, % TNT:</b>															
	Troud Test, % TNT: (a) 51															
	<b>Plate Dent Test:</b> Method															
	Condition															
<p><b>Flammability Index:</b></p> <p><b>Hygroscopicity:</b> % 30°C, 90% RH 0.02</p> <p><b>Volatility:</b></p>	Confined															
	Density, gm/cc															
	Brisance, % TNT															
	<b>Detonation Rate:</b> Confinement      Pressed Condition															
<table style="width: 100%;"> <tr><td>Charge Diameter, in.</td><td></td></tr> <tr><td>Density, gm/cc</td><td>2.0    3.0    4.0</td></tr> <tr><td>Rate, meters/second</td><td>3500    4250    5000</td></tr> </table>		Charge Diameter, in.		Density, gm/cc	2.0    3.0    4.0	Rate, meters/second	3500    4250    5000									
Charge Diameter, in.																
Density, gm/cc	2.0    3.0    4.0															
Rate, meters/second	3500    4250    5000															

AMCP 706-177

### **Mercury Fulminate**

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>					
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>				
Density, gm/cc		Hole Volume					
Charge Wt, lb		Hole Depth					
<b>Total No. of Fragments:</b>		<b>Color:</b> White to gray					
For TNT							
For Subject HE							
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Detonators and ingredient of priming compositions					
Density, gm/cc							
Charge Wt, lb							
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> psi x 10 <sup>3</sup>					
For TNT		3	5	10	12	15	20
For Subject HE		3.00	3.20	3.60	3.70	3.82	4.00
<b>Fragment Velocity:</b> ft/sec		<b>Loading Density:</b> gm/cc					
At 9 ft							
At 25½ ft							
Density, gm/cc							
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>					
<b>Air:</b>		<b>Method</b>					
Peak Pressure		Wet					
Impulse							
Energy							
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance)</b>					
Impulse		Class 9					
<b>Under Water:</b>		<b>Compatibility Group</b>					
Peak Pressure		Group M (wet)					
Impulse							
Energy		<b>Exudation</b>					
<b>Underground:</b>		None					
Peak Pressure							
Impulse							
Energy							
<b>Stab Sensitivity:</b>							
		<b>Density</b>	<b>Firing Point (inch-ounces)</b>				
		<u>gm/cc</u>	<u>0%</u>	<u>50%</u>	<u>100%</u>		
		3.91	3.2	4.3	5.5		
		4.26	1.6	2.6	5.5		
		4.32	1.6	2.6	4.0		
		4.50	1.6	2.5	4.0		
<b>Activation Energy:</b>							
		<u>kcal/mi</u>		29.81			
		Induction Period, sec		0.5-10			
<b>Heat of:</b>							
		Combustion, cal/gm		938			
		Explosion, cal/gm		427			
		Gas Volume, cc/gm		243			
		Formation, cal/gm		-226			
<b>Specific Heat:</b> cal/gm/°C		1.1					
<b>Thermal Conductivity:</b>		<u>cal/sec/cm/°C</u>		<u>1 x 10<sup>-4</sup></u>			

Mercury Fulminate

AMCP 706-177

Initiating Efficiency; Grams Required to Give Complete Initiation of:Fulminate, gm

TNT	0.25
Tetryl	0.20
RDX	0.19
PETN	0.17

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity to Static Discharge, Joules: (b) 0.025The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

Months Storage	979	Recrystallized Lots			Uncrystallized Lots	
		980	981	982	505-6-7/31	505-3-5/11
0	99.75	99.77	99.79	99.79	98.86	
4						98.7
6	99.36	99.45	99.54	99.47	95.95	98.7
8						97.4
9					94.95	
10						94.9
12	98.74	99.56	97.49	99.06	90.65	
13	98.26			98.79		
14	98.22					
15	97.52	99.30	99.30	98.19	83.76	
16	97.00		99.01	97.75		
17	95.70	98.66		96.69		
18	94.81	98.58	98.45	97.90	79.99	
23					74.52	
26					63.80	

Chemistry:

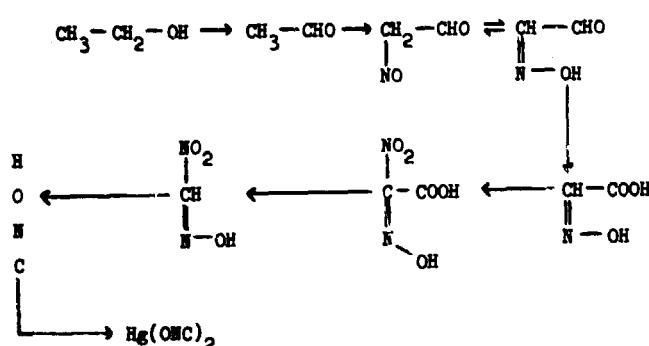
Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protective, coated if used with fulminate.

Solubility, Grams of Mercury Fulminate in 100 Grams of Water (%):

°C	%
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis)



Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fumes and subsequent appearance of fulminate crystals. Red fumes then appear as precipitation of the product accelerates, and then white fumes again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decantation, with water to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans., 204 (1800)). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium thiosulfate. Some poisonous cyanogen gas may be evolved.

References:<sup>43</sup>

- (a) Ph. Naum - Z ges Schieß-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1945.

<sup>43</sup>See footnote 1, page 10.

Mercury Fulminate

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(c) Also see the following Picatinny Arsenal Technical Reports on Mercury Fulminate:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	301	132	23	144	65	266	277	28	199
480	381	452	203	294	105	366	297	78	609
510	561	522	393	534	255	556	407	278	749
550	1651	582	433	624	285	566	537	318	849
610		782	833	694	365	865	567	788	999
660		882	1183	784	415	986	637	1838	1079
760		932	1393	874	425	1316	857		1389
1220		1192	2093	1104	1325	1486	1737		2179
1450		1352			1365	1556			
		1372				2146			
		1722							
		2032							

**AMCP 706-177 Metriol Trinitrate (MTN) Liquid (or Trimethylethane Trinitrate)**

<b>Composition:</b> %		<b>Molecular Weight:</b> (C <sub>3</sub> H <sub>9</sub> N <sub>3</sub> O <sub>9</sub> ) 255	
C	23.5	O <sub>2</sub> NO-CH <sub>2</sub>	
H	3.5	O <sub>2</sub> NO-CH <sub>2</sub>	C-CH <sub>3</sub>
N	16.6		
O	56.4	O <sub>2</sub> NO-CH <sub>2</sub>	
C/H Ratio 0.150			
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 47; (1 lb wt) 4 Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in. Sample Wt, mg		20	
<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe		<b>Boiling Point:</b> °C	
<b>Rifle Bullet Impact Test:</b> Trials %		<b>Refractive Index, n<sub>D</sub>:</b> n <sub>D<sup>20</sup></sub> 1.4752 n <sub>D<sup>25</sup></sub>	
Explosions Partials Burned Unaffected		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C cc/gm 1.9 120°C 135°C 150°C	
<b>200 Gram Bomb Sand Test:</b> Sand, gm		43.7	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Ignites 235 10 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Mortar, % TNT:</b> (a) 136 <b>Trexel Test, % TNT:</b> (b) 140	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brionce, % TNT	
<b>Flammability Index:</b>		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.07			
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 24			

Metric Trinitrate (NTN) Liquid

AMCP 706-777

<b>Fragmentation Test:</b>  <b>70 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 Inch HE, M42A1 Projectile, Lot KC-3:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b>  <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <b>Color:</b> Oily, slightly turbid  <b>Principal Uses:</b> Ingredient of rocket and double base propellants  <b>Method of Loading:</b>  <b>Loading Density:</b> gm/cc  <b>Storage:</b> Method: Liquid	Glass Cones	Steel Cones	Hole Volume		Hole Depth	
Glass Cones	Steel Cones							
Hole Volume								
Hole Depth								
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse		<b>Hazard Class (Quantity-Distance)</b>  <b>Compatibility Group:</b> Exudation						
<b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<b>Solubility in Water,</b> <u>gm/100 gm, at:</u>  25°C < 0.015 60°C < 0.015  <b>Heat of:</b> Combustion, cal/gm 2642  <u>Hydrolysis, % Acid:</u>  10 days at 22°C 0.018 5 days at 60°C 0.115						

Preparation:

Metricol (trimethylolmethylmethane) is obtained by the following procedure, based on work by Hosaeus (Annalen 276, 76 (1893)):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosaeus gives 199°C).

Metricol is nitrated by carefully mixing it with 3.5 parts of 65/35 HNO<sub>3</sub>/H<sub>2</sub>SO<sub>4</sub> maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with a sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MTN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World War II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References:<sup>44</sup>

- (a) A. H. Elatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
- (b) E. Burlot and M. Thomas, Mém poudr 29, 262 (1939).
- (c) Also see the following Picatinny Arsenal Technical Reports on Metricol Trinitrate: 1616 and 1817.

<sup>44</sup>See footnote 1, page 10.

<b>Composition:</b>		<b>Molecular Weight:</b>	71
%			
Ammonium Nitrate	40	Oxygen Balance:	
TNT	40	CO <sub>2</sub> %	-38
Aluminum	20	CO %	-20
C/H Ratio		Density: gm/cc	1.62-1.68
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Melting Point:</b> °C	
Bureau of Mines Apparatus, cm	35	<b>Freezing Point:</b> °C	
Sample Wt 20 mg		<b>Boiling Point:</b> °C	
Picatinny Arsenal Apparatus, in.	13	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	
Sample Wt, mg	27	n <sub>D</sub> <sup>25</sup>	
		n <sub>D</sub> <sup>30</sup>	
<b>FriCTION Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
<b>Rifle Bullet Impact Test:</b>	Trials	100°C	
Explosions	%	120°C	2.1
Partials		135°C	
Burned		150°C	
Unaffected		<b>200 Gram Bomb Sand Test:</b>	
<b>Explosion Temperature:</b> °C		Sand, gm	
Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b>	
1		Minimum Detonating Charge, gm	
5 Ignites	435	Mercury Fulminate	
10		Lead Azide	
15		Tetryl	
20		<b>Ballistic Mortar, % TNT:</b> (a) 143	
<b>75°C International Heat Test:</b>		<b>Trend Test, % TNT:</b> (b) 165	
% Loss in 48 Hrs		<b>Plate Dent Test:</b> (c)	
<b>100°C Heat Test:</b>		Method	B
% Loss, 1st 48 Hrs		Condition	Pressed
% Loss, 2nd 48 Hrs		Confined	No
Explosion in 100 Hrs		Density, gm/cc	1.73
<b>Flammability Index:</b>	100	Brisance, % TNT	66
<b>Hygroscopicity:</b> %		<b>Detonation Rate:</b> (d)	
<b>Volatility:</b>		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.6
		Density, gm/cc	1.68
		r <sub>c</sub> , meters/second	5820

<b>Booster Sex W-By Test:</b> Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	(e) Pressed 100 1.46 1.74	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
<b>Heat of:</b> Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	(f) 3160 1620 — — —	<b>Armor Plate Impact Test:</b> (f)  <b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec      828 Aluminum Fineness
<b>Specific Heat: cal/gm/°C</b> At -20°C Density, gm/cc	0.30 1.74	<b>500-lb General Purpose Bomb:</b>  <b>Plate Thickness, inches</b> 1 1½ 1½ 1¾
<b>Burning Rate:</b> cm/sec		<b>Bomb Drop Test:</b>
<b>Thermal Conductivity:</b> cal/sec/cm/°C Density, gm/cc	(b) 16.5 × 10 <sup>-4</sup> 1.74	<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>  Max Safe Drop, ft
<b>Coefficient of Expansion:</b> Linear, %/°C  <b>Volume, %/°C</b>		<b>500-lb General Purpose Bomb vs Concrete:</b>  <b>Height, ft</b> Trials Unaffected Low Order High Order
<b>Hardness, Mohs' Scale:</b>		<b>1000-lb General Purpose Bomb vs Concrete:</b>  <b>Height, ft</b> Trials Unaffected Low Order High Order
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc	(b) 5.03 × 10 <sup>10</sup> 0.73 × 10 <sup>6</sup> 1.66	
<b>Compressive Strength: lb/inch<sup>2</sup> (b)</b> Density, gm/cc	1910-2070 1.68	
<b>Vapor Pressure:</b> °C	mm Mercury	

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p> <p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p> <p><b>Blast (Relative to TNT):</b></p> <table border="0"> <tr> <td>Air:</td> <td></td> </tr> <tr> <td>Peak Pressure</td> <td>115</td> </tr> <tr> <td>Impulse</td> <td>116</td> </tr> <tr> <td>Energy</td> <td>133</td> </tr> <tr> <td>Air, Confined:</td> <td></td> </tr> <tr> <td>Impulse</td> <td>90</td> </tr> <tr> <td>Under Water:</td> <td></td> </tr> <tr> <td>Peak Pressure</td> <td>108</td> </tr> <tr> <td>Impulse</td> <td>126</td> </tr> <tr> <td>Energy</td> <td>140</td> </tr> <tr> <td>Underground:</td> <td></td> </tr> <tr> <td>Peak Pressure</td> <td>134</td> </tr> <tr> <td>Impulse</td> <td>139</td> </tr> <tr> <td>Energy</td> <td>147</td> </tr> </table>	Air:		Peak Pressure	115	Impulse	116	Energy	133	Air, Confined:		Impulse	90	Under Water:		Peak Pressure	108	Impulse	126	Energy	140	Underground:		Peak Pressure	134	Impulse	139	Energy	147	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table> <p><b>Color:</b> Gray</p> <p><b>Principal Uses:</b> Bombs and depth charges</p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density:</b> gm/cc      1.62-1.68</p> <p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table> <p><b>Preparation:</b></p> <p>Minol is a castable mixture consisting of 40 percent TNT, 40 percent ammonium nitrate, and 20 percent powdered aluminum and therefore can be prepared by adding the dry ingredients to molten TNT at 90°C under agitation. Minol also can be prepared by adding 25 parts of aluminum to 100 parts of 50/50 amatol previously prepared.</p>	Glass Cones	Steel Cones	Hole Volume		Hole Depth		Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	
Air:																																											
Peak Pressure	115																																										
Impulse	116																																										
Energy	133																																										
Air, Confined:																																											
Impulse	90																																										
Under Water:																																											
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Hazard Class (Quantity-Distance)	Class 9																																										
Compatibility Group	Group I																																										
Exudation																																											

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

<u>Composition, %:</u>	<u>Minol-1</u>	<u>Minol-2</u>	<u>Minol-3</u>
TNT	48	40	42
Ammonium Nitrate	42	40	38
Aluminum	10	20	20

References:<sup>45</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Meeserly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10, 303, 15 June 1949.
- (f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Technical Div Lecture, 9 April 1948.
- (h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

<sup>45</sup>See footnote 1, page 10.

<b>Composition:</b>		<b>Molecular Weight:</b>	40.6
%			
Oxidizing agent (Ammonium Perchlorate)	35.0	Oxygen Balance:	
Aluminum, atomized	26.2	CO <sub>2</sub> %	-44
Cupric Oxide	----	CO %	-37
Magnesium, atomized	26.2	Density: gm/cc	
Other ingredient (Tetryl)	9.7	Pressed	2.0
Calcium Stearate	1.9	Melting Point: °C	
Graphite, artificial	1.0	Freezing Point: °C	
C/H Ratio		Boiling Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		Refractive Index, n <sub>20</sub>	
Bureau of Mines Apparatus, cm	--	n <sub>20</sub>	
Sample Wt 20 mg		n <sub>20</sub>	
Picatinny Arsenal Apparatus, in.	13	n <sub>20</sub>	
Sample Wt, mg	22	Vacuum Stability Test:	
<b>Friction Pendulum Test:</b>		cc/40 Hrs, at	
Steel Shoe	Detonates	90°C	----
Fiber Shoe	Unaffected	100°C	0.47
		120°C	
		135°C	
		150°C	
<b>Rifle Bullet Impact Test:</b>	Trials	200 Gram Bomb Sand Test:	
	%	Sand, gm	10.6
Explosions		Sensitivity to Initiation:	
Partials		Minimum Detonating Charge, gm	
Burned		Mercury Fulminate	----
Unaffected		Lead Azide	0.20
		Tetryl	0.25
<b>Explosion Temperature:</b>	°C	Ballistic Merit, % TNT:	
Seconds, 0.1 (no cap used)	---	Treitz Test, % TNT:	
1	---	Plate Dent Test:	
5	285	Method	
10		Condition	
15		Confined	
20		Density, gm/cc	
<b>75°C International Heat Test:</b>		Brisance, % TNT	
% Loss in 48 Hrs			
Discoloration, fumes, odor	None	<b>Detonation Rate:</b>	
<b>100°C Heat Test:</b>		Confinement	
% Loss, 1st 48 Hrs	0.10	Condition	
% Loss, 2nd 48 Hrs	0.01	Charge Diameter, in.	
Explosion in 100 Hrs	None	Density, gm/cc	
<b>Flammability Index:</b>		Rate, meters/second	
<b>Hygroscopicity: %</b>			
<b>Volatility:</b>			

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  <b>Glass Cones      Steel Cones</b> Hole Volume Hole Depth	
	<b>Color:</b> Gray powder mixture	
	<b>Principal Uses:</b> Small caliber antiaircraft projectiles	
	<b>Method of Loading:</b> Pressed	
	<b>Loading Density: gm/cc</b> At 30,000 psi	~ 2.0
	<b>Storage:</b>  <b>Method</b> Dry	
	<b>Hazard Class (Quantity-Distance)</b> Class 9	
	<b>Compatibility Group</b> Group I Bureau of Explosives Classification Class A Exudation	
	<b>Heat of:</b>  Combustion, cal/gm      4087 Explosion, cal/gm      2087 Gas volume, cc/gm      212	
	<b>Performance Tests:</b> <u>20 mm T215E1 Projectile:</u>  NFOC Pressure Cube      35 APG Blast Cube      40	
	<b>Activation Energy:</b>  kcal/mol      12.5 Temp, °C Time to ignition, seconds      30°C to 380 1.78 x 10⁻⁴	

<b>Composition:</b> %		<b>Molecular Weight:</b> 42	
Oxidizing agent (Ammonium Perchlorate)	35.0	CO <sub>2</sub> %	-41
Aluminum, atomized	52.4	CO %	-43
Cupric Oxide	----	Density: gm/cc	Pressed 2.0
Magnesium, atomized	----	Melting Point: °C	
Other ingredients*	9.7	Freezing Point: °C	
Calcium Stearate	1.9	Boiling Point: °C	
Graphite, artificial	1.0	Refractive Index, n <sub>d20</sub> n <sub>d25</sub> n <sub>d30</sub>	
*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.		Vacuum Stability Test: cc/40 Hrs, at 90°C	----
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		100°C	0.21
Sample Wt 20 mg		120°C	
Picatinny Arsenal Apparatus, in.		135°C	
Sample Wt, mg		150°C	
<b>Friction Pendulum Test:</b>		200 Gram Bomb Sand Test: Sand, gm	11.5
Steel Shoe	Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm	
Fiber Shoe	Unaffected	Mercury Fulminate	----
<b>Rifle Bullet Impact Test:</b> Trials		Lead Azide	0.20
Explosions %		Tetryl	0.20
Partials		Ballistic Mortar, % TNT:	
Buried		Treud Test, % TNT:	
Unaffected		Plate Dent Test: Method	
<b>Explosion Temperature:</b> °C		Condition	
Seconds, 0.1 (in. cap used)	---	Confined	
1	---	Density, gm/cc	
5	375	Brisance, % TNT	
10		<b>Detonation Rate:</b>	
15		Confinement	
20		Condition	
<b>75°C International Heat Test:</b>		Charge Diameter, in.	
% Loss in 48 Hrs		Density, gm/cc	
Discoloration, fumes, odor		Rate, meters/second	
<b>100°C Heat Test:</b>			
% Loss, 1st 48 Hrs			
% Loss, 2nd 48 Hrs			
Explosion in 100 Hrs			
<b>Flammability Index:</b>			
<b>Hygroscopicity:</b> %			
<b>Volatility:</b>			

<b>Fragments Test:</b>			<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>			Glass Cones	Steel Cones
Density, gm/cc			Hole Volume	
Charge Wt, lb			Hole Depth	
<b>Total No. of Fragments:</b>			<b>Color:</b>	Gray
For TNT				
For Subject HE				
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>			<b>Principal Uses:</b> HE filler for small caliber projectiles	
Density, gm/cc				
Charge Wt, lb				
<b>Total No. of Fragments:</b>			<b>Method of Loading:</b>	Pressed
For TNT				
For Subject HE			<b>Loading Density:</b> gm/cc	2.0
<b>Fragment Velocity: ft/sec</b>			<b>Storage:</b>	
At 9 ft			Method	Dry
At 25½ ft			Hazard Class (Quantity-Distance)	Class 9
Density, gm/cc			Compatibility Group	Group I
			Bureau of Explosives Class A	
			Exudation	None
<b>Blast (Relative to TNT):</b>			<b>Heat off:</b>	
Air, Bare Charge:	<u>EW*</u>	<u>EV*</u>	Combustion, cal/gm	4.84
Peak Pressure	1.02	1.34	Explosion, cal/gm	14.2
Impulse	1.08	1.41	Gas volume, cc/gm	22
Energy				
Density, gm/cc		1.96		
Air, Confined:			<b>Performance Tests:</b>	
Impulse			20 mm T215E1 Projectile:	
<b>Cased Charge in Air:**</b>			NFOC Pressure Cube	29
Peak Pressure	1.09	1.44	APG Blast Cube	30
Impulse	1.16	1.53		
Energy	----	----	<b>Aviation Energy:</b>	
Density, gm/cc		1.98	kcal/mol	7.6
<b>Underground:</b>			Temp, °C	340 to 470
Peak Pressure			Time to ignition, seconds	$1.39 \times 10^{-2}$
Impulse				
Energy				
*EW, equivalent weight as compared to TNT; EV, equivalent volume as compared to TNT.				
**Strong paper-base phenolic case.				

Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity\*  
 (Reference g)

<u>Simulated Altitude,</u> <u>Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
	<u>Confined</u> <u>m/s</u>	<u>Unconfined</u> <u>m/s</u>	<u>Confined</u> <u>m/s</u>	<u>Unconfined</u> <u>m/s</u>
Ground			4730	
30,000	Charge would not		4530(3)	
60,000	propagate detonation.		4430	Charge would not propa- gate detona- tion.
90,000			4290	
Average			4495	

\*Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes\* (g)

<u>Explosive</u>	<u>Charge Diameter,</u> <u>Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground</u> <u>m/s</u>	<u>30,000</u> <u>m/s</u>	<u>60,000</u> <u>m/s</u>	<u>90,000</u> <u>m/s</u>
MOX-2B, density, gm/cc 207	1	2012	**	**	**
	2	3514	3351	3247	**

\*Outside diameter 2.54"; inside diameter 2.04"; length 7".

\*\*Charge would not propagate detonation.

<b>Composition:</b>	<b>Molecular Weight:</b> 45.6	
% Oxidizing agent (Potassium Nitrate) 18 Aluminum, atomized 50 Cupric Oxide -- Magnesium, atomized -- Other ingredients* 32 Calcium Stearate** 2.0 Graphite, artificial** 1.0 *29.1% RDX, 0.9% wax, and 2.0% TNT. **per cent added.	Oxygen Balance: CO <sub>2</sub> % -52 CO % -43	
	<b>Density:</b> gm/cc Pressed 2.0	
	<b>Melting Point:</b> °C	
	<b>Freezing Point:</b> °C	
	<b>Boiling Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 24	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup>	
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 0.57 120°C 135°C 150°C	
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 33.2	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) --- 1 --- 5 540 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs Discoloration, fumes, odor None	<b>Ballistic Mortar, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.35 % Loss, 2nd 48 Hrs 0.13 Explosion in 100 Hrs None	<b>Treitz Test, % TNT:</b>	
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
<b>Hygroscopicity:</b> %		
<b>Velocity:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

<b>Fragmentation Test:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>	
Density, gm/cc	Glass Cones
Charge Wt, lb	Steel Cones
<b>Total No. of Fragments:</b>	<b>Hole Volume</b>
For TNT	Hole Depth
For Subject HE	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>	
Density, gm/cc	<b>Color:</b>
Charge Wt, lb	Gray powder mixture
<b>Total No. of Fragments:</b>	<b>Principal Uses:</b>
For TNT	Small caliber antiaircraft projectiles
For Subject HE	
<b>Fragment Velocity: ft/sec</b>	<b>Method of Loading:</b>
At 9 ft	Pressed
At 25½ ft	
Densit., gm/cc	<b>Loading Density: gm/cc</b>
	At 30,000 psi ~ 2.0
<b>Blast (Relative to TNT):</b>	<b>Storage:</b>
<b>Air:</b>	Method
Peak Pressure	Dry
Impulse	
Energy	
<b>Air, Confined:</b>	<b>Hazard Class (Quantity-Distance)</b>
Impulse	Class 9
<b>Under Water:</b>	<b>Compatibility Group</b>
Peak Pressure	Group I
Impulse	Bureau of Explosives Class A
Energy	
<b>Underground:</b>	<b>Heat of:</b>
Peak Pressure	Combustion, cal/gm 4331
Impulse	Explosion, cal/gm 980
Energy	Gas volume, cc/gm 232
	<b>Performance Tests:</b>
	<b>20 mm T215EL Projectile:</b>
	NFOC Pressure Cube 37
	APG Blast Cube 52
	<b>Activation Energy:</b>
	kcal/mol
	Temp, °C
	Time to ignition, seconds
	Values not included due to erratic ignition under conditions of test.

<b>Composition:</b> % Oxidizing agent (Barium Nitrate) 18 Aluminum, atomized 50 Cupric Oxide -- Magnesium, atomized -- Other ingredients* 32 Calcium Stearate** 2.0 Graphite, artificial** 1.0 *29.1% RDX, 0.9% wax, and 2.0% TNT. **Per cent added.	<b>Molecular Weight:</b> 48
	<b>Oxygen Balance:</b> CO, % -53 CO % -43
	<b>Density:</b> gm./cc Pressed 2.0
	<b>Melting Point:</b> °C
	<b>Freezing Point:</b> °C
	<b>Boiling Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b> n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Sparks Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C --- 100°C 0.67 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 33.6
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) --- 1 --- 5 610 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15
<b>75°C International Heat Test:</b> % loss in 48 Hrs Discoloration, fumes, odor None	<b>Ballistic Mortar, % TNT:</b> Trauzl Test, % TNT
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.22 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Flammability Index:</b>	<b>Detonation Rate:</b>
<b>Hygroscopicity:</b> %	Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Volatility:</b>	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile - Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b> Gray powder mixture	
For TNT			
For Subject HE			
<b>3 inch HE, M42A1 Projectile - Lot KC-5:</b>		<b>Principal Use:</b> Small caliber antiaircraft projectiles	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Pressed	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		At 30,000 psi	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		<b>Method:</b> Dry	
Peak Pressure			
Impulse			
Energy		<b>Hazard Class (Quantity-Distance):</b> Class V	
<b>Air, Confined:</b>		<b>Compatibility Group:</b> Group I	
Impulse		Bureau of Explosives	
<b>Under Water:</b>		Class A	
Peak Pressure			
Impulse		<b>Heat of:</b>	
Energy		Combustion, cal/gm 4302	
		Explosion, cal/gm 709	
		Gas volume, cc/gm 208	
<b>Underground:</b>		<b>Performance Tests:</b>	
Peak Pressure		<b>20 mm T215E1 Projectile:</b>	
Impulse		NFOC Pressure Cube 43	
Energy		APG Blast Cube 53	
<b>Aviation Energy:</b>		<b>Values not included due to erratic ignition under conditions of test.</b>	
kcal/mol			
Temp, °C			
Time to ignition, seconds			

<b>Composition:</b>		<b>Molecular Weight:</b>	43
%			
Oxidizing agent	----		
Aluminum, atomized	49.2		
Cupric Oxide	19.7		
Magnesium, atomized	----		
Other ingredients*	29.6		
Calcium Stearate	----		
Graphite, artificial	1.5		
*26.7% RDX coated, 0.9% wax.			
C/H Ratio			
<b>Impact Sensitivity, 2 Kg Wt:</b>			
Bureau of Mines Apparatus, cm	78		
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.	19		
Sample Wt, mg	27		
<b>Friction Pendulum Test:</b>			
Steel Shoe	Unaffected		
Fiber Shoe	Unaffected		
<b>Rifle Bullet Impact Test:</b>	Tricks		
	%		
Explosions			
Partials			
Burned			
Unaffected			
<b>Explosion Temperature:</b>	°C		
Seconds, 0.1 (no cap used)	---		
1	---		
5	510		
10			
15			
20			
<b>75°C International Heat Test:</b>			
% Loss in 48 Hrs	0.02/10 gm		
Discoloration, fumes, odor	None		
<b>100°C Heat Test:</b>			
% Loss, 1st 48 Hrs	0.00		
% Loss, 2nd 48 Hrs	0.00		
Explosion in 100 Hrs	None		
<b>Flammability Index:</b>			
<b>Hygroscopicity: %</b>			
30°C, 90% RH, two week:	0.79		
<b>Volatility:</b>			
<b>Molecular Weight:</b>			
<b>Oxygen Balance:</b>			
CO <sub>2</sub> %	-50		
CO %	-42		
<b>Density:</b> gm/cc			
<b>Melting Point:</b> °C			
<b>Freezing Point:</b> °C			
<b>Boiling Point:</b> °C			
<b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup>			
	n <sub>D</sub> <sup>25</sup>		
	n <sub>D</sub> <sup>30</sup>		
<b>Vacuum Stability Test:</b>			
cc/40 Hrs, at			
90°C	----		
100°C		0.43	
120°C			
135°C			
150°C			
<b>200 Gram Bomb Sand Test:</b>			
Sand, gm	10.8		
<b>Sensitivity to Initiation:</b>			
Minimum Detonating Charge, gm			
Mercury Fulminate	----		
Lead Azide	0.20		
Tetryl	0.16		
<b>Ballistic Mortar, % TNT:</b>			
<b>Trouxi Test, % TNT:</b>			
<b>Plate Dent Test:</b>			
Method			
Condition			
Confined			
Density, gm/cc			
Brisance, % TNT			
<b>Detonation Rate:</b>			
Confinement			
Condition			
Charge Diameter, in.			
Density, gm/cc			
Rate, meters/second			

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b> Gray powder mixture	
For TNT			
For Subject HE			
3 inch HE, M42A1 Projectile, Lot KC-5:		<b>Principal Uses:</b> Small caliber antiaircraft projectiles	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Pressed	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		At 30,000 psi	~2.0
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		<b>Method</b>	
Air:		Dry	
Peak Pressure			
Impulse			
Energy			
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance)</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group</b>	
Peak Pressure		Grp p I	
Impulse		Bureau of Explosives	
Energy		Class A	
<b>Underground:</b>		<b>Heat of:</b>	
Peak Pressure		Combustion, cal/gm	4293
Impulse		Explosion, cal/gm	750
Energy		Gas volume, cc/gm	204
<b>Activation Energy:</b>			
kcal/mg <sub>1</sub>			
temp, °C			
Time to Ignition, seconds		Values not included due to erratic ignition under conditions of test.	

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer's 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about 50°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hand-rolled to crush any conglomerates formed, and blended by hand before use.

TNT-Coated Barium Nitrate - Thirty grams of TNT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under agitation. The temperature of the TNT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% TNT is reduced to an intimate mixture by hand-rolling and blending before use.

TNT-Coated Potassium Nitrate - The TNT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

RDX/TNT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and TNT in hot ethanol. After adding the ammonium perchlorate, the tray is stirred until most of the solvent is evaporated. The treated ammonium perchlorate is spread on a tray to dry overnight. Agglomerates formed during the process are crushed by hand-rolling and blending the mixture before use.

TNT-Coated RDX - Sixty grams of molten TNT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the TNT-RDX slurry is maintained at about 90°C and stirring is continued for half an hour. After cooling to about 50°C, the TNT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/TNT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

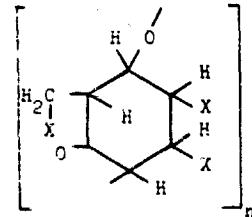
References:<sup>46</sup>

- (a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task 1, National Fireworks Ordnance Corporation, First Yearly Summary, August 1950 to August 1951.
- (b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, December 1952.
- (c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.
- (d) A. O. Mirarchi, Properties of Explosives. MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.
- (e) A. T. Wilson, Development of MOX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.
- (f) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.
- (g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DII-19-020-501-ORD-(P)-58).
- (h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3755, 5 April 1956.
- (i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204, 2205.

<sup>46</sup>See footnote 1, p.

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Nitrocellulose, -2.6% (NC)

<b>Composition:</b> %		<b>Molecular Weight:</b> $(272.39)_n$
C 26.46 H 2.78 N 12.60 O 58.16 X= $\text{NO}_2$		<b>Oxygen Balance:</b> CO <sub>2</sub> % -35 CO % 0.6
C/H Ratio 0.23		<b>Density:</b> gm/cc
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 8 Sample Wt 20 mg		<b>Melting Point:</b> °C Decomposes
Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		<b>Freezing Point:</b> °C
<b>Friction Pendulum Test:</b> Steel Shoe Filter Shoe		<b>Boiling Point:</b> °C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected		<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
<b>Explosive Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Decomposes 170 10 15 20		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 0.17 100°C 1.0 120°C 16 hours 11.+ 135°C 150°C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>200 Gram Bomb Sand Test:</b> Sand, gm 45.0
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl
<b>Flammability Index:</b>		<b>Ballistic Mortar, % TNT:</b>
<b>Hygroscopicity:</b> % 30°C, 90% RH 3		<b>Trouxl Test, % TNT:</b>
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 0.0		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

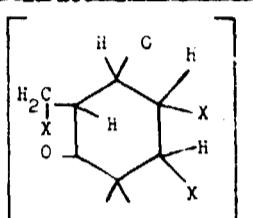
Nitrocellulose, 13.45% N (NC)

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<b>Composition:</b> %		<b>Molecular Weight:</b> (286.34) <sub>n</sub>
C 25.29 H 2.52 N 13.45 O 58.74 X=ONO <sub>2</sub>		<b>Oxygen Balance:</b> CO <sub>2</sub> % -29 CO % 4.7
C/H Ratio 0.23		<b>Density:</b> gm/cc
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 9 Sample Wt 20 mg		<b>Melting Point:</b> °C Decomposes
Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		<b>Freezing Point:</b> °C
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		<b>Boiling Point:</b> °C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected		<b>Refractive Index, n<sub>d</sub>:</b> n <sub>20</sub> n <sub>25</sub> n <sub>30</sub>
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 230 10 15 20		<b>Vacuum Ignition Test:</b> cc/40 H.s. at 90°C 0.42 100°C 1.5 120°C 11.4 135°C 150°C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>200 Gram Bomb Sand Test:</b> Sand, gm 49.0
<b>100°C Heat Test:</b> % Loss, 1st 48 hrs 0.3 % Loss, 2nd 48 hrs 0.0 Explosion in 100 Hrs None		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl
<b>Flammability Index:</b>		<b>Ballistic Mortar, % TNT:</b> 125
<b>Hygroscopicity:</b> % 30°C, 90% RH ~ 2		<b>Treuzi Test, % TNT:</b>
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 0.0		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc 1.20 Rate, meters/second 7300

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Nitrocellulose, 14.14% N (NC)

<b>Composition:</b> %	<b>Molecular Weight:</b> $(297.15)_n$
C 24.25 H 2.37 N 14.14 O 59.24 X=NO <sub>2</sub>	Oxygen Balance: CO <sub>2</sub> % -24 CO % 8
	Density: gm/cc 1.65-1.70
C/H Ratio 0.23	Melting Point: °C Decomposes
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 8 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	Freezing Point: °C
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	Boiling Point: °C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>Refractive Index, n<sub>D</sub>:</b> n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub> n <sub>D<sub>30</sub></sub>
<b>Explosion Temperature:</b> °C Seconds, 0.1 (inc cap used) 1 5 10 15 20	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 1.46 100°C 14 hours 11.+ 120°C 16 hours 11.+ 135°C 150°C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>200 Gram Bomb Sand Test:</b> Sand, gm 52.3
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 43 Hrs Explosion in 100 Hrs	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide C.10 Tetryl
<b>Flammability Index:</b>	<b>Ballistic Mortar, % TNT:</b>
<b>Hygroscopicity:</b> % 30°C, 90% RH ~ 1	<b>Trouxi Test, % TNT:</b>
<b>Volatility:</b> 60°C, mg/cm <sup>2</sup> /hr 0.0	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		White	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Melted or Loading:</b>	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
		Method	Wet (8% to 30% water)
		Hazard Class (Quantity-Distance) Class 12	
		Compatibility Group	Group M (wet)
		Exudation	None
<b>Blast (Relative to TNT):</b>		<b>Heat of:</b>	
<b>Air:</b>		Combustion, cal/gm 2409* 2313** 2228***	
Peak Pressure		Explosion, cal/gm 855* 965** 1058***	
Impulse		Gas Volume, cc/gm 919* 883** 853***	
Energy		Formation, cal/gm 617* 561** 513***	
<b>Air, Confined:</b>		* 12.6% N	
Impulse		** 13.45% N	
<b>Under Water:</b>		*** 14.14% N	
Peak Pressure		<b>Vapor Pressure:</b>	
Impulse		<u>°C</u>	<u>mm Mercury</u>
Energy		25	0.00
		60	0.00

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Nitrocellulose (NC)

Solubility in Water, gm/100 gm, at:	12.6% N	13.45% N	14.0% N
25°C	Insoluble	Insoluble	Insoluble
60°C	Insoluble	Insoluble	Insoluble
<u>Solubility, gm/100 gm, 25°C, in:</u>			
Ether	Insoluble	Insoluble	Insoluble
Alcohol	Very slight- ly soluble	Practically insoluble	Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + β)
Acetone	Soluble	Soluble	Soluble
<u>24-Hour Hydrolysis Test,</u> <u>in Nitric Acid.</u>	1.22	1.03	

Preparation of Nitrocellulose from Cotton Linters:  
(Laboratory Procedure)

Nitration: Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

- a. for 12.6% N: H<sub>2</sub>SO<sub>4</sub> 63.5%, HNO<sub>3</sub> 21%, H<sub>2</sub>O 15.5%
- b. for 13.4% N: H<sub>2</sub>SO<sub>4</sub> 68%, HNO<sub>3</sub> 22%, H<sub>2</sub>O 10.0%

Temperature of acid at the start 34°C

Time of nitration 24 minutes

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocellulose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as H<sub>2</sub>SO<sub>4</sub>. The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

Pulping: The nitrocellulose is then pulped in a laboratory Holland-type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

Poaching: After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little sodium carbonate solution is added to maintain the mixture faintly alkaline to phenolphthalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poaching is as follows:

Nitrocellulose (NC)

4 hours boiling with or without sodium carbonate  
 2 hours boiling without sodium carbonate  
 1 hour boiling without sodium carbonate  
 1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

Washing: The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel and R. Bottger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

Pyrocellulose, a type of nitrocellulose of 12.6% nitrogen content, completely soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (1895). This material, when colloidal, formed the first smokeless powder for military use in the United States (1898).

Guncotton for military purposes may contain a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as flame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blended nitrocellulose) of 15.15% to 13.25% nitrogen content.

Destruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitrocellulose has been added.

References:<sup>47</sup>

- (a) See the following Picatinny Arsenal Technical Reports on Nitrocellulose:

<sup>47</sup>See footnote 1, page 10.

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Nitrocellulose (NC)

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
10	41	72	13	4	125	86	167	8	19
390	101	332	33	24	475	576	327	198	29
420	231	402	43	114	485	586	407	208	69
660	351	422	133	174	495	796	717	278	169
730	551	542	233	194	555	916	787	388	279
960	831	572	253	334	705	1016	987	408	499
1020	851	652	273	374	965	1026	1187	588	659
1100	971	662	63	394	1065	1066	1197	718	669
1150	1031	752	673	724	125	1206	1267	758	709
1199	1041	802	683	804	1135	1256	1297	778	739
1210	1071	952	773	894	1205	1276	1327	808	779
1240	1151	1012	793	1024	1265	1306	1407	838	809
1300	1201	1032	963	1054	1275	1316	1427	878	909
1320	1221	1142	1023	1074	1365	1516	1447	1058	1119
1350	1231	1242	123	1084	1375	1556	1487	1228	1159
1410	1331	1282	1273	1174	1745	1616	1587	1238	1249
1430	1351	1362	1443	1274	1755	1786	1637	1248	1309
1490	1391	1392	1653	1304	1845	2056	1717	1348	1329
1580	1401	1642	1753	1314	1905		1817	1398	1349
1660	1421	1812	1813	1384	1915		1827	1478	1399
1810	1501	1852	186?	1394	1955		1847	1528	1439
1830	1541	1912	1813	1454			2107	1638	1449
1990	1681	1992	1973	1674			2137	1678	1619
2210	1691	2022		1754				1838	1799
	1731	2102		1814				1898	1809
	1751			1824				1918	1869
	1811			2144				2098	2119
	1831							2208	2189
	1841								
	1851								
	1931								
	1961								
	1991								
	2071								
	2101								
	2181								
	2201								

Nitroglycerin (Liquid)

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<b>Composition:</b> %		<b>Molecular Weight:</b> (C <sub>3</sub> H <sub>5</sub> N <sub>3</sub> O <sub>9</sub> ) 227	
C	15.9	H <sub>2</sub> C — O <sub>2</sub> NO	
H	2.2	HC — O <sub>2</sub> NO	
N	18.5	H <sub>2</sub> C — O <sub>2</sub> NO	
O	63.4		
C/H Ratio 0.109			
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt, 20 mg		15	
Picatinny Arsenal Apparatus, in. 1 lb wt Sample Wt, mg		1	
<b>Friction Pendulum Test:</b> Steel Shoe Explodes			
Fiber Shoe			
<b>Rifle Bullet Impact Test:</b> Trials			
Explosions	100		
Portals	0		
Burned	0		
Unaffected	0		
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)			
1			
5	Explodes 222		
10			
15			
20			
<b>75° : International Heat Test:</b> % Loss in 48 Hrs			
<b>100°C Heat Test:</b>			
% Loss, 1st 48 Hrs	3.6		
% Loss, 2nd 48 Hrs	3.5		
Expansion in 100 Hrs	None		
<b>Flammability Index:</b>			
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.06			
<b>Vapor Density:</b> 60°C, mg/cm <sup>3</sup> /hr 0.11			
<b>Oxygen Balance:</b>			
CO <sub>2</sub> %	3.5		
CO %	24.5		
<b>Density:</b> gm/cc 25°C, Liquid 1.59, 20°C, Liquid 1.596			
<b>Melting Point:</b> °C Labile form 2.2 Stable form 13.2			
<b>Freezing Point:</b> °C			
<b>Boiling Point:</b> °C Decomposes 145			
<b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup> 1.4732 n <sub>D</sub> <sup>25</sup> 1.4733 n <sub>D</sub> <sup>30</sup>			
<b>Vacuum Stability Test:</b> cc/40 Hrs, at			
90°C cc/gm/6 hrs	1.6		
100°C cc/gm/16 hrs	11+		
120°C			
135°C			
150°C			
<b>200 Gram Bomb Sand Test:</b> Sand, gm Liquid method 51.5			
<b>Sensitivity to Initiators:</b>			
Minimum Detonating Charge, gm			
Mercury Fulminate			
Lead Azide			
Tetryl			
<b>Ballistic Mortar, % TNT:</b> (a) 140			
<b>Torsion Test, % TNT:</b> (b) 181			
<b>Plate Dent Test:</b>			
Method			
Condition			
Confined			
Density, gm/cc			
Brisance, % TNT			
<b>Detonation Rate:</b>			
Confinement		Class	Steel
Condition	Liquid	Liquid	Liquid
Charge Diameter, in.	0.39	1.25	
Density, gm/cc	1.6	1.6	
Rate, meters/second	1600-1900	7700	

Nitroglycerin (Liquid)

<b>Booster Sensitivity Test:</b>		<b>Decomposition Equation:</b>	
Condition		Oxygen, atoms/sec (Z/sec)	$10^{17.3}$ $10^{19.2}$
Tetryl, gm		Heat, kilocalorie/mole ( $\Delta H$ , kcal/mol)	41.4      45.0
Wax, in. for 50% Detonation		Temperature Range, °C	90-135      125-150
Wax, gm		Phase	Liquid      Liquid
Density, gm/cc			
<b>Heat of:</b>		<b>Armor Plate Impact Test:</b>	
Combustion, cal/gm	1616	40 mm Master Projectile: 50% Inert, Velocity, ft/sec	
Explosion, cal/gm	1600	Aluminum Fineness	
Gas Volume, cc/gm	725		
Formation, cal/gm	400		
Fusion, cal/gm			
Detonation, cal/gm	1486		
<b>Specific Heat: cal/gm/°C</b>		<b>500-lb General Purpose Bomb:</b>	
Liquid	0.356	Plate Thickness, inches	
Solid	0.315	1 1½ 1¾ 2	
<b>Burning Rate:</b> cm/sec		<b>Bomb Drop Test:</b>	
<b>Thermal Conductivity:</b> cal/sec/cm/°C		17, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:	
<b>Coefficient of Expansion:</b> Linear, %/°C		Max Safe Drop, ft	
Volume, %/°C		500-lb General Purpose Bomb vs Concrete:	
<b>Hardness, Mohr's Scale:</b>		Height, ft	
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup>		Trials	
Density, gm/cc		Unaffected	
<b>Compressive Strength:</b> lb/inch <sup>2</sup>		Low Order	
<b>Vapor Pressure:</b>		High Order	
°C	mm Mercury	°C	mm Mercury
20	0.00025	60	0.0188
30	0.00083	70	0.043
40	0.0024	80	0.098
50	0.0073	90	0.23

Nitroglycerin (Liquid)

AMCP 706-1/7

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	Hole Volume		
Charge Wt, lb	Hole Depth		
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Colorless	
For Subject HE,			
3 inch HE, M42A1 Projectile, Lot KC-5:		<b>Principal Uses:</b> Propellant ingredient, demolition explosive ingredient, grenade burster ingredient	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
<b>Density, gm/cc</b>		<b>Storage:</b>	
		Method With acetone or other desensitizer, generally not stored	
<b>Blast (Relative to TNT):</b>		<b>Hazard Class (Quantity-Distance)</b>	
Air:		Class 9	
Peak Pressure		<b>Compatibility Group</b>	
Impulse			
Energy		<b>Exudation</b>	
<b>Air, Confined:</b>		<b>Heat of Transition, cal/gm:</b>	
Impulse		<b>Transition:</b>	
<b>Under Water:</b>		Liquid → labile                        5.2	
Peak Pressure		Labile → stable                        28.0	
Impulse		Liquid → stable                        33.2	
Energy		<b>Hydrolysis, % Acid:</b>	
<b>Underground:</b>		10 days at 22°C                      < 0.002	
Peak Pressure		5 days at 60°C                      0.005	
Impulse		<b>82.1°C KI Test:</b>	
Energy		Minutes                                    10+	

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Nitroglycerin (Liquid)

Gas Evolved at Atmospheric Pressure, cc:

Sample Wt, gm	1.6
Temperature, °C	65
Time, hours	20
Volume of gas, cc	nil
	75
	40
	nil

Viscosity: (c)

°C	Centipoises
10	69.2
20	36.0
30	21.0
40	13.6
50	9.4
60	6.8

Fragmentation Test:

20 mm HE, Mark 1, Projectile, Total No.  
of Fragments for:

Nitroglycerin	22
Tetranitromethane	17

Minimum Propagating Diameter: (d)

% Dimethylphthalate in NG	Min. Propagating Diameter, inches	Min. Diameter for Curves in Inches
0	(5/16 inches)	5/16
5	--	1/8
10	1/3	3/16
15	1/4	5/32
20	3/4	7/32
22.5	1	1 1/2
25	1.55	2

Sensitivity to Electrostatic Discharge, cmiles (test condition, unconfined;  
no value given for confinement): > 12.5

Solubility, gram of nitroglycerin/100 gm (g) of:

°C	Water		Alcohol		Trichlorethylene		Carbon Tetrachloride	
	g	g	°C	g	°C	g	°C	g
15	0.16	0	37.5		Rm	22	Rm	2
20	0.18	20	54.0					
50	0.25							

Nitroglycerin (Liquid)

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<u>Carbon Disulfide</u>	<u>gm/100 gm (%)</u> , at 25°C in
°C	%
Ambient	1
Ether	"
2:1, Ether:Alcohol	> 100
Acetone	"

Soluble in all Proportions in:

Methanol	Phenol
Acetone	Pyridine
Ether	Xylene
Ethyl acetate	Nitrobenzene
Amyl acetate	p-Nitrotoluene
Methyl nitrate	Liquid TNT
Ethyl nitrate	Chloroform
Nitroglycol	Ethyl chloride
Tetranitrodiglycerine	Ethyl bromide
Acetic acid	Tetrachloroethylene
Benzene	Dichloroethylene
Toluene	Trimethyleneglycol Dinitrate

Solubility in NG, of:

<u>Alcohol</u>	<u>TNT</u>	<u>TNT</u>	<u>Water</u>				
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	3.4	20	35	20	30	25	0.06
20	5.4	"	"	"	"	"	"
50	"	"	"	"	"	"	"

Preparation:

Glycerine is usually nitrated at 25°C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15°C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

Nitroglycerin (Liquid)Origin:

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (*Mem Acad Torino* (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and non-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (British Patent 1345 (1867)). Later developments led to gelatine dynamites, ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Ballistite (Nobel, British Patent 1471 (1888)) and Cordite (Bel and Dewar, British Patents 5614 and 11,664 (1889)).

Destruction by Chemical Decomposition:

Nitroglycerin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ). Heat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycerin and continued until solution is complete.

References:<sup>48</sup>

(a) A. R. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(b) Ph. Macum, Z ges Schiess-Sprengstoffw, pp. 181, 239, 267 (27 June 1932).

(c) Landolt - Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables:

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol I-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

(d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5609, 3 December 1945.

(e) Also see the following Picatinny Arsenal Technical Reports on Nitroglycerin:

0	1	2	3	4	5	6	7	8	9
620	511	652	233	454	1155	1206	817	768	69
660	551	672	343	494	1235	1456	837	1348	249
800	701	732	673	1024	1955	1496	1197	1398	579
1020	891	922	903	1074	2015	1556	1297	1738	709
1150	911	1142	1023	1084		1616	1637	1918	1349
1220	1031	1232	1443	1454		1786	1817	2098	1359
1410	1041	1362	1643	1524		1816	1847		2119
1620	1151	1542	1663	1624		1896			
1680	1191	1662	1863	1671		2056			
1221	1692	1993	1754						
1611	1742								
1651	1752								
1691	1992								
1731									
1781									
1851									
1931									
2021									
2181									
2201									

<sup>48</sup>See footnote 1, page 10.

Nitroguanidine

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<b>Composition:</b>	<b>Molecular Weight:</b> $(\text{CH}_4\text{N}_4\text{O}_2)$	104
% C 11.5 H 3.9 N 53.8 O 30.8 C/H Ratio 0.038	<b>Oxygen Balance:</b> CO <sub>2</sub> % -31 CO % -15.4	
	<b>Density:</b> gm/cc <b>Crystal</b>	1.72
	<b>Melting Point:</b> °C	232
	<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 47	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in. 26	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b>	
Sample Wt, mg 7	n <sub>25</sub> <sup>D</sup>	
	n <sub>30</sub> <sup>D</sup>	
<b>Friction Pendulum Test:</b> (e) Steel Shoe Unaffected Fibre Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.37 120°C 0.44 135°C 150°C	
<b>Rifle Bullet Impact Test:</b> 5 Trials (e) % Explosions 0 Partick 0 Burned 0 Unaffected 100	<b>200 Gram Bomb Sand Test:</b> Sand, gm 36.0	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 5 Decomposes 275 10 15 20	<b>Sensitivity to Ignition:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.04	<b>Ballistic Mortar, % TNT:</b> (a) 104 <b>Trenz Test, % TNT:</b> (b) 101	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.18 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None	<b>Plate Dent Test:</b> (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 95	
<b>Flammability Index:</b>	<b>Detonation Rate:</b> (e) Confinement Condition Charge Diameter, in. Density, gm/cc 1.55 Rate, meters/second 7650	
<b>Hygroscoicity:</b> % 30°C, 90% RH None		
<b>Volatility:</b> None		

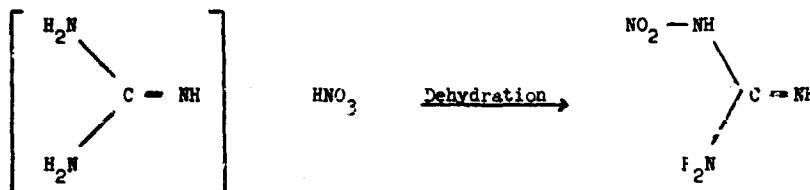
<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		Colorless	
For Subject HE		<b>Principal Uses:</b>	
3 inch HE, M42A1 Projectile, Lot KC-3:		Propellant composition ingredient, bursting charge ingredient	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT			
For Subject HE		<b>Loading Density: gm/cc</b>	
<b>Fragment Velocity: ft/sec</b>		At 3000 psi	
At 9 ft		0.95	
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		<b>Method</b>	
Air:		Dry	
Peak Pressure			
Impulse			
Energy			
Air, Confined:		<b>Hazard Class (Quantity-Distance)</b>	
Impulse		Class 9	
<b>Under Water:</b>		<b>Compatibility Group</b>	
Peak Pressure		Group I	
Impulse			
Energy		<b>Exudation</b>	
<b>Underground:</b>		<b>Solubility, gm/100 gm (%), in:</b>	
Peak Pressure		0°C	
Impulse		Water	0.44
Energy		100	9.0
Air, Confined:		1.0 N Potassium	
Impulse		Hydroxide	1.4
Under Water:		40% Sulfuric Acid	3.4+
Peak Pressure			8.0+
Impulse		* gm/100 cc solution	
Energy		<b>Booster Sensitivity Test:</b>	
Underground:		(d)	
Peak Pressure		Condition	Pressed
Impulse		Tetryl, gm	100
Energy		Wax, in. for 50% Detonation	0.67
Air, Confined:		Density, gm/cc	1.41
Impulse		<b>Heat of:</b>	
Under Water:		Combustion, cal/gm	1995
Peak Pressure		Explosion, cal/gm	721
Impulse		Gas Volume, cc/gm	1077
Energy		Formation, cal/gm	227

Nitroguanidine

AMCP 706-177

Preparation:

(Chemistry of Powder and Explosives, Davis)



Four hundred grams of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10°C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Nitroguanidine was first prepared in 1877 by Jousselin, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Nitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Heating is continued for one-half hour.

References:<sup>49</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Canadian Report, CE-12, 1 May-15 August 1941.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetralin in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Departments of the Army and the Air Force TM 9-1910/TU 11A-1-34, Military Explosives, April 1949.

<sup>49</sup>See footnote 1, page 10.

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Nitroguanidine

(\*) Also see the following Picatinny Arsenal Technical Reports on Nitroguanidine:

<u>2</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1490	1391	1282	1183	1336	907	758	1439
	2181	1392	1423		2177		1749
	2201	2142	2193				

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

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<b>Composition:</b> % C 16.8 $\text{O}_2\text{NO}-\text{CH}_2$ H 2.1 $\text{O}_2\text{NO}-\text{CH}_2$ C = NO <sub>2</sub> N 19.6 O 61.5 $\text{O}_2\text{NO}-\text{CH}_2$ C/H Ratio 0.126		<b>Molecular Weight:</b> (C <sub>4</sub> H <sub>6</sub> N <sub>2</sub> O <sub>11</sub> ) 286 <b>Oxygen Balance:</b> CO <sub>2</sub> % 0.0 CO % 22 <b>Density:</b> gm/cc 20°C 1.64 <b>Melting Point:</b> °C <b>Freezing Point:</b> °C -39
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 25 Sample Wt 20 mg <b>Picatinny Arsenal Apparatus, in.</b> Sample Wt, mg		<b>Boiling Point:</b> °C <b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>20</sup> 1.4896 n <sub>D</sub> <sup>25</sup> 1.4874
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm 0.2 mm particle absorbed by 0.1 g of explosive 20
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Ignites 185 10 15 20		<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate Lead Azide Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Factor, % TNT:</b> <b>Tread Test, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		<b>Flame Dent Test:</b> <b>Method</b> <b>Condition</b> <b>Confined</b> <b>Density, gm/cc</b> <b>Brisance, % TNT</b>
<b>Flammability Index:</b>		<b>Detonation Rate:</b> <b>Confinement</b> Glass (1 mm wall) <b>Condition</b> Liquid <b>Charge Diameter, in.</b> 0.39 <b>Density, gm/cc</b> 1.64 <b>Rate, meters/second</b> 7360
<b>Hygroscopicity:</b> %		
<b>Volatility:</b> 25°C, mg/cm <sup>2</sup> /24 hrs 0.127 x 10 <sup>-3</sup>		

Nitroisobutylglycerol Trinitrate (NITRIN) Liquid

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <b>Color:</b> Yellow oil	Glass Cones	Steel Cones	Hole Volume		Hole Depth	
Glass Cones	Steel Cones							
Hole Volume								
Hole Depth								
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Principal Uses:</b> Gelatinizing agent for nitrocellulose						
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<b>Method of Loading:</b>  <b>Loading Density: gm/cc</b>  <b>Storage:</b> Method Liquid						
		<b>Hazard Class (Quantity-Distance)</b>  <b>Compatibility Group</b>  <b>Exudation</b>						
		<b>Solubility:</b> Soluble in methyl and ethyl alcohols, acetone, ether, ethylenedichloride, chloroform and benzene.  Insoluble in water, carbon disulphide, and petroleum ether. <b>Toxicity:</b> Slight, decidedly less than nitroglycerin. <b>Gelatinizing Action:</b> Slight on nitrocellulose. <b>82.2°C KI Test:</b> Minutes 2						

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

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Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hemi-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30°C, and then the heat of reaction is allowed to raise the temperature to 60°C, and the mixture then heated two hours at 90°C. The reaction mixture is then concentrated at reduced pressure and diluted, and this process repeated several times to remove formaldehyde. After the final concentration the cooled mixture is filtered and the crystalline product recrystallized from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/36/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (*Z ges Schiess - Sprengstoffw* L, 43 (1912)). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References:<sup>50</sup>

- (a) H. A. Aaronson, Study of Explosives Derived from Nitroparaffins, PATR No. 1125, 24 October 1941.
- (b) M. Aubry, *Mém poudr*, 25, 197-204 (1932-33); CA 27, 4083 (1933).
- (c) A. Stettbacher, *Mitrocellulose* 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).
- (d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).
- (e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, *Ind Eng Chem* 32, 427-9 (1940); CA 34, 3235 (1940).
- (f) A. Stettbacher, *Z ges Schiess Sprengstoffw* 37, 62-4 (1942); CA 38, 255 (1944).

<sup>50</sup>See footnote 1, page 10.

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Nitrostarch Demolition Explosive (NSX)

<b>Composition:</b> %		<b>Molecular Weight:</b>	325
Nitrostarch (12.50% N)	49	Oxygen Balance: CO <sub>2</sub> %	-19
Barium Nitrate	40	CO %	8
Mononitronaphthalene	7	Density: gm/cc	
Parenitroaniline	3	Melting Point: °C	
Oil	1	Freezing Point: °C	
<b>C/H Ratio</b>		Boiling Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	21	Refractive Index, n <sub>d20</sub> <sup>o</sup>	
Sample Wt 20 mg		n <sub>d25</sub> <sup>o</sup>	
Picatinny Arsenal Apparatus, in.	8	n <sub>d30</sub> <sup>o</sup>	
Sample Wt, mg		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
<b>Friction Pendulum Test:</b>		90°C	
Steel Shoe	Crackles, snaps	100°C	11+
Fiber Shoe	Unaffected	120°C	
<b>Rifle Bullet Impact Test: 10 Trials</b>	8 Trials*	135°C	
	%	150°C	
Explosions	97	<b>200 Gram Bomb Shock Test:</b>	
Partials	0	Sand, gm	39.5
Burned	0		
Unaffected	10	<b>Sensitivity to Initiation:</b>	
*Packed in paper	87	Minimum Detonating Charge, gm	
Explosion Temperature: °C		Mercury Fulminate	0.26
Seconds, 0.1 (no cap used)	--	Lead Azide	--
1	--	Tetryl	--
5 Decomposes	195	<b>Ballistic Mortar, % TNT:</b> (s)	96
10		<b>Troux Test, % TNT:</b>	
15		<b>Plate Dent Test:</b>	
20		Method	
<b>75°C International Heat Test:</b>		Condition	
% Loss in 48 Hrs	0.2	Confined	
<b>100°C Heat Test:</b>		Density, gm/cc	
% Loss, 1st 48 Hrs	0.3	Brisance, % TNT	
% Loss, 2nd 48 Hrs	0.3		
Explosion in 100 Hrs	None	<b>Detonation Rate:</b>	
		Confinement	
<b>Flammability Index:</b>		Condition	
<b>Hygroscopicity: % 30°C, 90% RH</b>	2.1	Charge Diameter, in.	
<b>Volatility:</b>		Density, gm/cc	
		Rate, meters/second	

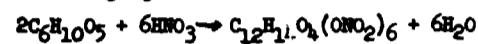
Nitrostarch Demolition Explosive (NSX)

AMCP 706-177

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>	
	Glass Cones	Steel Cones
	Hole Volume	
	Hole Depth	
	<b>Color:</b>	
	<b>Principal Uses:</b> Demolition, bursting charges, and priming compositions	
	<b>Method of Loading:</b> Hand tamped	
	<b>Loading Density:</b> gm/cc Apparent 0.92	
	<b>Storage:</b>	
	Method Dry	
Hazard Class (Quantity-Distance) Class 9		
Compatibility Group Group I		
Exposure None		
<b>120°C Heat Test:</b>		
Salmon Pink Minutes 70		
Red Fumes 255		
Explodes 256		

Preparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:



Tapioca starch is considered the best for nitration purposes, although other starches give fairly stable products. The starch, pretreated to remove oils, fats and water soluble impurities, is dried and screened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%–63% HNO<sub>3</sub> and 37%–38% H<sub>2</sub>SO<sub>4</sub>) is done slowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to 35°–40°C with air. This product is so sensitive even a static discharge might cause explosion.

Nitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Nitrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 22, 290 (1833)). T. J. Pelouse studied xyloidine further and reported its explosive properties (Compt rend L, 713 (1838)). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References:<sup>51</sup>

- (a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.
- (b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).
- (c) Also see the following Picatinny Arsenal Technical Reports on Nitrostarch Explosives:

1	2	4	7	8	9
1611	782	1034	1117	838	1269
2032				848	

<sup>51</sup>See footnote 1, page 10.

Ocotol, 70/30

<b>Composition:</b> %		<b>Molecular Weight:</b>	265
HNX	70	<b>Oxygen Balance:</b> CO, %	-38
TNT	30	CO %	-7.5
C/H Ratio		<b>Density:</b> gm/cc	Cast 1.80
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm		<b>Melting Point:</b> °C	
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
P cotimny Arsenal Apparatus, in.	18	<b>Boiling Point:</b> °C	
Sample Wt, mg	26	<b>Refractive Index:</b> $n_{D}^{20}$	
Friktion Pendulum Test:		$n_{D}^{20}$	
Steel Shoe	Unaffected	$n_{D}^{20}$	
Fiber Shoe	Unaffected	$n_{D}^{20}$	
Rifle Bullet Impact Test: Trials	%	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Explosions		90°C	----
Partials		100°C	----
Burned		120°C	0.37
Unaffected		135°C	
		150°C	
200 Gram Bomb Sand Test:		<b>200 Gram Bomb Sand Test:</b>	
		Sand, gm Exploratory	58.4
Explosion Temperature: °C		<b>Sensitivity to Initiators:</b>	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5 Flames erratically	335	Lead Azide	0.30
10		Tetryl	----
15			
20		<b>Ballistic Meter, % TNT:</b>	115
75°C International Heat Test: % Loss in 48 Hrs		<b>Tread Test, % TNT:</b>	
100°C Heat Test: % Loss, 1st 48 Hrs		<b>Plate Dowd Test:</b>	
% Loss, 2nd 48 Hrs		Method	
Explosion in 100 Hrs		Condition	
		Confined	
<b>Flammability Index:</b>		Density, gm/cc	
<b>Hygroscopicity:</b> %		Brisance, % TNT	
<b>Volatility:</b>		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.80
		Rate, meters/second	8377

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<b>Booster Sensitivity Test:</b>	<b>Decomposition Equation:</b>		
Condition	Oxygen, atoms/sec (Z/sec)		
Tetry, gm	Heat, kilocalorie/mole (ΔH, kcal/mol)		
Wax, in. for 50% Detonation	Temperature Range, °C		
Wax, gm	Phase		
Density, gm/cc			
<b>Heat of:</b>	<b>Armor Plate Impact Test:</b>		
Combustion, cal/gm	2722		
Explosion, cal/gm	1074		
Gas Volume, cc/gm	847		
Formation, cal/gm	----		
Fusion, cal/gm			
<b>Specific Heat:</b> c <sub>p</sub> /gm/°C		<b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec.	
<b>Burning Rate:</b> cm/sec		Aluminum Fineness	
<b>Thermal Conductivity:</b> cal/sec/cm/°C		<b>500-lb General Purpose Bombs:</b>	
<b>Coefficient of Expansion:</b> Linear, %/°C		Plate Thickness, inches	
Volume, %/°C		1	
<b>Hardness, Mohs' Scale:</b>		1 1/4	
<b>Young's Modulus:</b>		1 1/2	
E', dynes/cm <sup>2</sup>		1 3/4	
E, lb/inch <sup>2</sup>			
Density, gm/cc			
<b>Compressive Strength:</b> lb/inch <sup>2</sup>	1510 See below	<b>Bomb Drop Test:</b>	
<b>Vapor Pressure:</b> °C mm Mercury		<b>T7, 2000-lb Semi-Armored Piercing Bomb vs Concrete:</b>	
<b>Compressive Strength:</b> lb/inch <sup>2</sup>	*	Max Safe Drop, ft	
Average (10 tests)	1510	<b>500-lb General Purpose Bomb vs Concrete:</b>	
High	1740	Height, ft	
Low	1330	Trials	
		Unaffected	
		Low Order	
		High Order	
		<b>1000-lb General Purpose Bomb vs Concrete:</b>	
		Height, ft	
		Trials	
		Unaffected	
		Low Order	
		High Order	
		<b>Ultimate Deformation:</b> %	
		Average (10 tests)	2.26
		High	2.58
		Low	1.97

\*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (7,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

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Fragmentation Test:  (1) 100 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  Fragment Velocity, ft/sec At 9 ft At 25½ ft Density, gm/cc	Shaped Charge Effectiveness, TNT = 100:	
	Glass Cones	Steel Cones
	Hole Volume	
	Hole Depth	
	Color:	Buff
	Principal Uses: HE projectile and bomb filler	
	Method of Loading:	Cast
	Loading Density: gm/cc	1.80
	Storage:	
	Method	Dry
Hazard Class (Quantity-Distance)		Class 9
Compatibility Group		Group I
Exudation		
Work to Produce Rupture: ft-lb/inch <sup>3</sup> *		
Average (10 tests)		1.55
High		1.87
Low		1.10
Efflux Viscosity, Saybolt Seconds:		5 9
*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.		

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Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity\*  
 (Reference b)

Explosive	Simulated Altitude, Feet	One-Inch Column		Two-Inch Column	
		Confined		Unconfined	
		m/s	m/s	m/s	m/s
70/30, RDX/TNT; density, gm/cc 1.62	Ground	7900	8100	7660	8030
	30,000	8020	8120	7900(4)	7800
	60,000	8040	8140	8010	7950
	90,000	8060	7980	8010	7710
	Average	8005	8085	7895	7873
70/30, HMX/TNT; density, gm/cc 1.61	Ground	7960	7900(4)	7870	7640(4)
	30,000	8050	8060	7930	7710
	60,000	8020	7930	7890	7650
	90,000	7950	8000	7940	7650
	Average	7995	7973	7908	7663

\*70/30 Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by ( ). A 26 gm tetry booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes\* (g)

Explosive	Charge Diameter, Inches	Simulated Altitude, Feet			
		Ground	30,000	60,000	90,000
		m/s	m/s	m/s	m/s
70/30, RDX/TNT	1	3415	3672	3666	3685
	2	4647	5192	5236	6011
70/30, HMX/TNT	1	3366	3680	4014	3617
	2	4703	5464	6089	6111

\*Outside diameter 2.54"; inside diameter 2.04"; length 7".

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Tensile Strength:\*

	lb/inch <sup>2</sup>
Average (8 tests)	169
High	204
Low	128

\*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:\*

	lb/inch <sup>2</sup>
Average (10 tests)	73,200
High	79,300
Low	63,00

\*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: ( )

Critical Pressure	92,000 psi*
Density, gm/cc	1.72

\*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm M1 HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1297
2 - 5	665
5 - 10	497
10 - 25	661
25 - 50	471
50 - 75	247
75 - 150	322
150 - 750	295
750 - 2500	12
Total Number	4467

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Octol, 75/25

<b>Composition:</b>		<b>Molecular Weight:</b>	276
%			
IBX	75	Oxygen Balance:	
TNT	25	CO <sub>2</sub> %	-35
		CO %	-63
		Density: gm/cc	Cast 1.81
C/H Ratio		Melting Point: °C	
		Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point: °C</b>	
Bureau of Mines Apparatus, cm	--		
Sample Wt 20 mg		Refractive Index, n <sub>20</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in.	17	n <sub>20</sub> <sup>D</sup>	
Sample Wt, mg	25	n <sub>30</sub> <sup>D</sup>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
<b>20/16 Bullet Impact Test: 10 Trials %</b>	<b>3/16" Steel      1/8" Al</b>	100°C	----
Explosions	70	120°C	0.39
Partials	--	135°C	
Burned	--	150°C	
Unaffected	30		
<b>Explosion Temperature:</b>	°C	<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5 Flames erratically	350	Lead Azide	0.30
10		Tetryl	----
15			
20		<b>Ballistic Mater, % TNT:</b>	116
<b>75°C Intermittent Heat Test:</b>		<b>Trexal Test, % TNT:</b>	
% Loss in 48 Hrs			
<b>100°C Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss, 1st 48 Hrs		Method	
% Loss, 2nd 48 Hrs		Condition	
Explosion in 100 Hrs		Confined	
		Density, gm/cc	
<b>Flammability Index:</b>		Brisance, % TNT	
<b>Hygroscopicity: %</b>			
<b>Volatility:</b>		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.81
		Rate, meters/second	8643

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Booster Sensitivity Test:		Decomposition Equation:
Condition		Oxygen, atoms/sec (Z/sec)
Tetryl, gm		Heat, kilocalorie/mole (ΔH, kcal/mol)
Wax, in. for 50% Detonation		Temperature Range, °C
Wax, gm		Phase
Density, gm/cc		
Heat of:		Armor Plate Impact Test:
Combustion, cal/gm	2676	60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec
Explosion, cal/gm	1131	Aluminum Fineness
Gas Volume, cc/gm	830	
Formation, cal/gm		500-lb General Purpose Bomb:
Fusion, cal/gm	29.4*	Plate Thickness, inches
*Calculated for 76.9% HMX, 23.1% TNT.		1
Specific Heat: cal/gm/°C	**	1 1/4
-79°C	0.200	1 1/2
-80° to +80°C	0.240	1 1/8
33° to 74°C	0.245	
90° to 150°C	0.323	
**Determined for 76.9% HMX, 23.1% TNT.		
Burning Rate:		Bomb Drop Test:
cm/sec		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Thermal Conductivity:		Max Safe Drop, ft
cal/sec/cm/°C		500-lb General Purpose Bomb vs Concrete:
Coefficient of Expansion:		Height, ft
Linear, %/°C		Trials
Volume, %/°C		Unaffected
Hardness, Mohr's Scale:		Low Order
Young's Modulus:		High Order
E', dynes/cm²		1000-lb General Purpose Bomb vs Concrete:
E, lb/inch²		Height, ft
Density, gm/cc		Trials
Compressive Strength: lb/inch²	1340	Unaffected
	See below	Low Order
Vapor Pressure:		High Order
°C mm Mercury		
Compressive Strength: lb/inch²	***	Ultimate Deformation: %
Average (10 tests)	1340	Average (10 tests)
High	1560	2.43
Low	1040	2.69
		2.04

\*\*\*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>			
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones		
Density, gm/cc		Hole Volume			
Charge Wt, lb		Hole Depth			
<b>Total No. of Fragments:</b>					
For TNT		Color:	Buff		
For Subject HE		<b>Principal Uses:</b> HE projectile and bomb filler			
3 inch HE, M43A1 Projectile, Lot KC-5:					
Density, gm/cc					
Charge Wt, lb					
<b>Total No. of Fragments:</b>					
For TNT		Method of Loading:	Cast		
For Subject HE		Loading Density: gm/cc	1.81		
<b>Fragment Velocity: ft/sec</b>					
At 9 ft		Storage:			
At 25½ ft		Method	Dry		
Density, gm/cc		Hazard Class (Quantity-Distance)	Class 9		
<b>Blast (Relative to TNT):</b>					
Air:		Compatibility Group	Group I		
Peak Pressure		Exudation			
Impulse					
Energy					
Air, Confined:					
Impulse					
Under Water:					
Peak Pressure					
Impulse					
Energy					
Underground:					
Peak Pressure					
Impulse					
Energy					
<u>Work to Produce Rupture: ft-lb/inch<sup>3</sup></u> *					
Average (10 tests) 1.31					
High 1.57					
Low 1.07					
<u>Efflux Viscosity, Saybolt Seconds:</u> 9.0					
*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.					

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Fragment Velocity Test: (a)

M26 Hand Grenade:

Explosive	Average Fragment Velocity, ft/sec over 1st 6 feet
Composition B	4948
75/25 Cyclotol	4908
75/25 Octol	5124

Tensile Strength:\*

	lb/inch <sup>2</sup>
Average (10 tests)	266
High	330
Low	226

\*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:\*

	lb/inch <sup>2</sup>
Average (10 tests)	62,100
High	75,900
Low	55,200

\*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test: (a)

Critical Pressure	76,000 psi*
Density, gm/cc	1.80

\*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test: (a)

105 mm M1 HE Projectile:

Weight Group, grains	No. of Fragments
1/2 - 2	1611
2 - 5	777
5 - 10	535
10 - 25	719
25 - 50	480
50 - 75	246
75 - 150	339
150 - 750	293
750 - 2500	8
Total Number	5008

Preparation:

Water-wet EMX is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References:<sup>52</sup>

- (a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."
- (b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DA-19-020-501-ORD-(P)-58).

<sup>52</sup>See footnote 1, page 10.

<b>Composition:</b>	<b>Molecular Weight:</b> 245	
%		
RDX	90	Oxygen Solance:
Polystyrene (unmodified)	8.5	CO <sub>2</sub> % -62
Dioctylphthalate	1.5	CO % -18
C/H Ratio		<b>Density: gm/cc</b>
		Unpressed 0.81
		Bullet pressed at 30,000 psi 1.62
<b>Impact Sensitivity, 2 Kg Wt:</b>	<b>Boiling Point: °C</b>	
Bureau of Mines Apparatus, cm	28	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	15	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>
Sample Wt, mg	20	n <sub>D</sub> <sup>20</sup>
		n <sub>D</sub> <sup>25</sup>
<b>Friction Pendulum Test:</b>	<b>Vacuum Stability Test:</b>	
Steel Shoe	Unaffected	cc/40 Hrs, at
Fiber Shoe	Unaffected	90°C -----
		100°C -----
<b>Rifle Bullet Impact Test: 10 Trials *</b>	120°C 0.41	
	135°C	
Explosions	10	150°C
Partials	90	
Burned	0	<b>200 Gram Bomb Shock Test:</b>
Unaffected	0	Sond, gm
<b>Explosion Temperature:</b> °C	<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm
1	---	Mercury Fulminate
5 Shocks	275	Lod Azide
10		Tetryl
15		
20		<b>Ballistic Mortar, % TNT:</b>
<b>75°C International Heat Test:</b>	<b>Trend Test, % TNT:</b>	
% Loss in 48 hrs		
<b>100°C Heat Test:</b>	<b>Plate Dent Test:</b>	
% Loss, 1st 48 Hrs	0.00	Method
% Loss, 2nd 48 Hrs	0.00	Condition
Explosion in 100 Hrs	None	Confined
		Density, gm/cc
<b>Flammability Index:</b>	<b>Brisance, % TNT:</b>	
<b>Hygroscopicity: %</b>		
* Test procedure described in PATR No. 2247, May 1956.	<b>Detonative Rate:</b>	
	Confine.nent	
	Condition	
	Charge Diameter, in.	
	Density, gm/cc	
	Rate, meters/second	

<b>Booster Sensitivity Test:</b>	<b>Decomposition Equation:</b>				
Condition	Oxygen, atoms/sec (Z/sec)				
Tetryl, gm	Heat, kilocalorie/mole (ΔH, kcal/mol)				
Wax, in. for 50% Detonation	Temperature Range, °C				
Wax, gm	Phase				
Density, gm/cc					
<b>Heat of:</b>	<b>Armor Plate Impact Test:</b>				
Combustion, cal/gm	3027				
Explosion, cal/gm	983				
Gas Volume, cc/gm					
Formation, cal/gm					
Fusion, cal/gm					
<b>Specific Heat: cal/gm/°C</b>	<b>500-lb General Purpose Bomb:</b>				
	Plate Thickness, inches				
	1				
	1 1/4				
	1 1/2				
	1 3/4				
<b>Burning Rate:</b>	<b>Bomb Drop Test:</b>				
cm/sec	<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>				
	Max Safe Drop, ft				
<b>Thermal Conductivity:</b>	<b>500-lb General Purpose Bomb vs Concrete:</b>				
cal/sec/cm/°C	Height, ft				
<b>Coefficient of Expansion:</b>	Trials				
Linear, %/°C	Unaffected				
<b>Volume, %/°C</b>	Low Order				
<b>Hardness, Mohs' Scale:</b>	High Order				
<b>Young's Modulus:</b>	See below	<b>1000-lb General Purpose Bomb vs Concrete:</b>			
E', dynes/cm <sup>2</sup>		Height, ft			
E, lb/inch <sup>2</sup>		Trials			
Density, gm/cc		Unaffected			
<b>Compressive Strength: lb/inch<sup>2</sup></b>	2403	2149			
Percent	8.9	13.1			
<b>Vapor Pressure:</b>	<b>Young's Modulus: * (a) Temperature</b>				
'C	mm Mercury				
<b>Young's Modulus: * (a)</b>	Ambient	95°C			
E, lb/inch <sup>2</sup> (avg of 5)	39,953	34,831			
Density, gm/cc	1.60	1.57			

\*Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 psi with 30-second dwell.

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones      Steel Cones</b>	
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		White	
For Subject HE		<b>Principal Uses:</b> High mechanical strength explosive	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Method of Loading:</b>	
Density, gm/cc		Pressed	
Charge Wt, lb		<b>Loading Density: gm/cc      Pressed, psi x 10<sup>3</sup></b>	
<b>Total No. of Fragments:</b>		0      10      20      30	
For TNT		1.10      1.49      1.59      1.62	
For Subject HE		<b>Storage:</b>	
<b>Fragment Velocity: ft/sec</b>		<b>Method</b>	
At 9 ft		Dry	
At 25½ ft		<b>Hazard Class (Quantity-Distance)</b>	
Density, gm/cc		Class 9	
<b>Blast (Relative to TNT):</b>		<b>Compatibility Group</b>	
Air:		Group I	
Peak Pressure		<b>Exudation</b>	
Impulse		None	
Energy		<b>Rockwell Hardness, "R" Scale: (a)</b>	
Air, Confined:		1/2 inch diameter penetrator, 60 Kg Load:	
Impulse		<b>Pellet No.*</b>	
Under Water:		<b>Specific Gravity</b>	
Peak Pressure		<b>Hardness</b>	
Impulse		1      1.624      84	
Energy		2      1.623      90	
Underground:		3      1.611      84	
Peak Pressure		4      1.600      80	
Impulse		5      1.590      75	
Energy		6      1.571      73	
		7      1.548      62	
		8      1.524      49	
*Pellets (Lot HOL-F-93) were 1-1/2 inches in diameter and 3/4 inch high.			

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PB-RDX

Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid  
Pellets\* to Initiation by Type II Special Blasting Caps (a)

Pellets	Gap (Distance From Base of Cap to Pellet), Inches						
	0.250	0.300	0.350	0.400	0.450	0.500	0.750
<u>PB-RDX with Pellet Density 1.55 gm/cc</u>							
No. of Trials	8	5	6	2	1	1	
Average Depth of Plate Indentation, inches **	0.082	0.090	0.087	0.080	0.080	—	—
No. of Failures	0	1	3	4	1	1	1
<u>PB-RDX with Pellet Density 1.60 gm/cc</u>							
No. of Trials	3	8	9	4	3	5	2
Average Depth of Plate Indentation, inches **	0.090	0.089	0.087	0.088	0.087	0.075	—
No. of Failures	0	0	2	3	2	3	2
<u>98/2 RDX/Stearic Acid With Pellet Density 1.63 gm/cc</u>							
No. of Trials	5	3	5	2	5	5	5
Average Depth of Plate Indentation, inches **	0.109	0.096	0.095	0.092	0.097	0.087	—
No. of Failures	0	1	0	3	4	4	5

\* Pellets 0.92 inch diameter, 0.375 inch height.

\*\* Mild steel plate 5" x 5" x 1".

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT M1 Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307A1 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boosted.

Preparation:

The purchase description sheet for polystyrene-bonded RDX (X-PA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylphthalate. The specified percentage of RDX shall consist of a mixture of 73% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

<u>Through U. S. Standard</u>		
<u>Sieve No.</u>	<u>Minimum %</u>	<u>Maximum %</u>
6	100	--
12	60	--
20	--	2
35	--	0

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. LA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handling and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthalate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of H<sub>2</sub>O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75°C by introducing steam into the jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10°C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dioctylphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

Commission, Report No. IA-1448). The specific formulation of 90/8.5/1.5 RDX/polystyrene/dioctylphthalate was subsequently standardized by Los Alamos. This explosive, originally designated PBX, has been redesignated PB-RDX. The detailed requirements for the present polystyrene-bonded RDX(PB-RDX) are given in purchase description X-PA-PD-1082, 25 October 1956.

References:<sup>53</sup>

- (a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, Characteristics of Polystyrene-Bonded RDX(PB-RDX), PATR No. 2497, April 1958.
- (b) A. J. Pascasio, The Suitability of a Bare PBX Booster Pellet in the 2.75 Inch M1 HEAT Rocket Head, PATR No. 2271, November 1955.
- (c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded RDX, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-T-16 Series A (PAC 1081), 5 March 1953.
- (d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307Al (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TM3-5204, October 1957.

<sup>53</sup>See footnote 1, page 10.

Pentaerythritol Trinitrate (PETRIN)

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<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>5</sub> H <sub>9</sub> N <sub>3</sub> O <sub>10</sub> )	271
C 22.1  H 3.3  N 15.5  O 59.1  C/H Ratio 0.141	$\begin{array}{c} \text{CH}_2\text{ONO}_2 \\   \\ \text{HOCH}_2-\text{C}-\text{CH}_2\text{ONO}_2 \\   \\ \text{CH}_2\text{ONO}_2 \end{array}$	<b>Oxygen Balance:</b> CO <sub>2</sub> % -27 CO % 3
		<b>Density:</b> gm/cc 1.54
		<b>Melting Point:</b> °C 26 to 28
		<b>Freezing Point:</b> °C
		<b>Boiling Point:</b> °C 4 mm Hg Decomposes 130
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38	<b>Refractive Index:</b> n <sub>D<sub>20</sub></sub> n <sub>D<sub>25</sub></sub> n <sub>D<sub>30</sub></sub>	
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 2.54 to 5.69 120°C 135°C 150°C	
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Trend Test, % TNT:</b>	
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined	
<b>Hygroscopicity:</b> %	Density, gm/cc Brisance, % TNT	
<b>Volatility:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

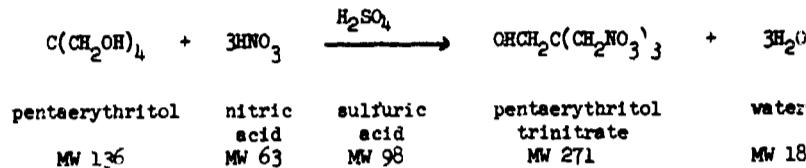
Pentaerythritol Trinitrate (PETRIN)

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Gloss Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT		White	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Explosive, propellant or igniter ingredient	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
		Method	Dry
		<b>Hazard Class (Quantity-Distance)</b>	
		<b>Compatibility Group</b>	
		Exudation	None
<b>Blast (Relative to TNT):</b>		<b>PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.</b>	
<b>Air:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Air, Con. Med:</b>			
Impulse			
<b>Under Water:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Underground:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Absolute Viscosity, poises:</b>			
Temp, 17°C	14.8		
23°C	4.3		
28°C	3.0		
36°C	1.2		
		<b>Heat of:</b>	
		Explosion, cal/gm	1204

Pentaerythritol Trinitrate (PETRIN)

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Preparation:



The earliest procedure used for the manufacture of PETRIN was that developed at Allegheny Ballistics Laboratory. In this process, called the "A process," 80%  $\text{HNO}_3$  and the solid pentaerythritol were charged to the reactor and 80%  $\text{H}_2\text{SO}_4$  was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammonium carbonate, after which the PETRIN was precipitated by the addition of water. After filtration, the PETRIN was recovered from the filtrate by stripping off the solvent under vacuum. Yields by this process averaged about 40%.

An improved process, called the "B process," used the same primary reaction procedure but a different work-up procedure. After the reaction holding period, water was added to dilute the mixed acid and the batch was extracted *in situ* with methylene chloride. The organic layer was separated, neutralized with aqueous sodium bicarbonate, and stripped of methylene chloride under vacuum to yield the product directly. Yields by this process were about 50% and quality of the product was much improved over that of the "A process."

The "C process," currently in use, involves essentially the simultaneous synthesis and extraction of PETRIN from the reaction mixture. Methylen chloride approximately equal to the total weight of the other components is added to the reaction mixture before the sulfuric acid. After a suitable time following the addition of sulfuric acid, the solvent is removed and replaced by fresh solvent one or more times. The combined extracts are neutralized and concentrated. Because of their initially relatively large volume, PETRIN may be removed by filtration from the concentrated PETRIN solution before the final solvent is stripped. Yields by this process have been 60% to 65%.

Origin:

The nitration products of pentaerythritol or its derivatives containing not more than three  $\text{NO}_2$  groups were patented for use as explosives, propellants or ignition materials in 1936 (German Patents 638,432 and 638,433; CA 31, 1212 (1937)).

A process in which pentaerythritol monoacetate was converted to pentaerythritol trinitrate monoacetate, which was then saponified under carefully controlled conditions to PETRIN, was reported in 1954 (N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 76, 1304). PETRIN was also prepared by the nitration of pentaerythritol with a mixture of 80%  $\text{HNO}_3$  and 80%  $\text{H}_2\text{SO}_4$  in 1955 (A. T. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

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Pentaerythritol Trinitrate (PETRIN)

References:<sup>54</sup>

- (a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Trinitrate Monocrylate and Petrin Acrylate Propellants, 12 Mar. 1956.
- (b) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, p. 65, Reinhold Publishing Corporation, New York, 1958.
- (c) R. H. Pierson, An Infrared Spectrophotometric Method for Determination of Acetone Content of Pentaerythritoltrinitrate, U.S. Naval Ordnance Test Station Report Note 1577, NAVORD Report No. 5649, 3 February 1958.

<sup>54</sup>See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate)  
(Trinitropentaerythritol Acrylate)

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<b>Composition:</b> % C 29.5 H 3.4 N 12.9 O 54.2  C/H Ratio 0.239	<b>Molecular Weight:</b> (C <sub>8</sub> H <sub>11</sub> N <sub>3</sub> O <sub>11</sub> ) 325  <b>Oxygen Balance:</b> CO <sub>2</sub> % -54 CO % -12  <b>Density:</b> gm/cc  <b>Melting Point:</b> °C 78 to 79  <b>Freezing Point:</b> °C  <b>Boiling Point:</b> °C  <b>Refractive Index:</b> n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>200 Gram Bomb Sand Test:</b> Sand, gm
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 10 15 20	<b>Ballistic Mortar, % TNT:</b>  <b>Treuzi Test, % TNT:</b>  <b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	  <b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	
<b>Flammability Index:</b>	
<b>Hygroscopicity:</b> % Nil	
<b>Volatility:</b>	

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Pentaerythritol Trinitroacrylate (PETRIN Acrylate)

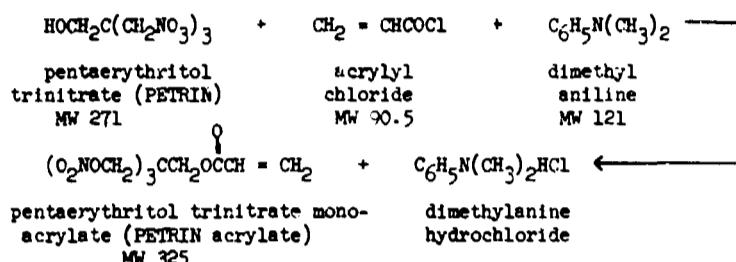
<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>			<b>Color:</b> White
For TNT			
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>			<b>Principal Uses:</b> Ingredient of composite rocket propellants
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>			<b>Method of Loading:</b>
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft		Method	Dry at temperatures below melting point
At 25½ ft		Hazard Class (Quantity-Distance)	
Density, gm/cc		Compatibility Group	
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
Air:		Exudation	None
Peak Pressure			
Impulse			
Energy			
Air, Compressed:		<b>Heat of:</b>	
Impulse		Combustion, cal/gm	2923
Under Water:		Explosion, cal/gm	791
Peak Pressure			
Impulse			
Energy			
Underground:			
Peak Pressure			
Impulse			
Energy			

Pentaerythritol Trinitroacrylate (PETRIN Acrylate)

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Preparation:

(a)



The original synthesis for PETRIN acrylate employed trifluoroacetic anhydride and glacial acrylic acid as the acrylation agent for PETRIN. These two materials were charged to a reaction vessel and the initial reaction was controlled by the slow addition of PETRIN at a temperature of 10° to 15°C. Following a period of one hour, the batch was drowned in water, precipitating the PETRIN acrylate. This solid was separated by filtration, dissolved in chloroform, and neutralized in solution with sodium bicarbonate. The product was then crystallized during a period of 16 hours at 0°C and dried under vacuum to remove traces of solvent. The yield for this process was about 60%.

A significant improvement in yield (to about 74%) and purity (approximately 98%) was realized by the substitution of methanol for chloroform and crystallization of the product from the solution without neutralization, residual acid being removed by washing the filter cake with water.

Because of the high cost and hygroscopic nature of trifluoroacetic anhydride, a new process, based on dimethylaniline and acrylyl chloride, was considered. This process is currently under development in the Rohm and Haas Chemical Processing facilities and is not considered optimum. Yields averaged 46% and product purities averaged 93.5%.

PETRIN Acrylate Propellants:

PETRIN acrylate could be used as a monopropellant because it has a specific impulse of 214 lb-sec/lb and a burning rate of 0.2 in/sec. The addition of an oxidizer increases both the impulse and burning rate.

A composition which presently appears most promising is as follows:

	Composition NM
PETRIN acrylate (> 97% purity), %	34.3 (binder)
Triethylene glycol trinitrate, %	11.8 (plasticizer)
Glycol diacrylate, %	2.9 (crosslinker)
Ammonium perchlorate, %	51.0 (oxidizer)
Hydroquinone, %	0.014 (polymerization inhibitor)

Measured specific impulse 238 lb-sec/lb, at density of 1.3.

Reference:<sup>5</sup>

- (a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Tetranitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 1956.

<sup>5</sup>See footnote 1, page 10.

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Pentolite, 50/50; 10/90

Composition:			Molecular Weight:	<u>50/50</u>	<u>10/90</u>
%				262	234
PETN	50	10	Oxygen Balance:		
TNT	50	90	CO <sub>2</sub> %	-42	-68
			CO %	-5	-21
C/H Ratio			Density: gm/cc	1.65	1.60
Impact Sensitivity, 2 Kg Wt:	<u>50/50</u>	<u>10/90</u>	Melting Point: °C		76
Bureau of Mines Apparatus, cm	34	65	Freezing Point: °C		
Sample Wt 20 mg			Boiling Point: °C		
Picatinny Arsenal Apparatus, in.	12	14	Refractive Index, n <sub>20</sub> <sup>20</sup>	n <sub>20</sub> <sup>20</sup>	
Sample Wt, mg	15	18	n <sub>20</sub> <sup>20</sup>	n <sub>20</sub> <sup>20</sup>	
Friction Pendulum Test:			Vacuum Stability Test:	<u>50/50</u>	<u>10/90</u>
Steel Shoe		Unaffected	cc/40 Hrs, at		
Fiber Shoe		Unaffected	90°C		
Rifle Bullet Impact Test: 25 Trials, 50/50			100°C	3.0	3.0
Explosions	72		120°C	11+	11+
Partials	20		135°C	--	--
Burned	0		150°C	--	--
Unaffected	8		200 Gram Bomb Sond Test:		
Expllosion Temperature: °C, 50/50			Sond, gm	55.6	49.5
Seconds, 0.1 (no cap used)	290		Sensitivity to Initiation:	<u>50/50</u>	
1	266		Minimum Detonating Charge, gm		
5 Decomposes	220		Mercury Fulminate	0.19*	
10	204		Lead Azide	0.13*	
15	197		Tetryl	--	
20	>190		*Alternative initiating charges.		
75°C International Heat Test:			Ballistic Mortar, % TNT:	(a)	126
% Loss in 48 Hrs			Trevizi Test, % TNT:	(b)	122
100°C Heat Test:	<u>50/50</u>		Plate Dent Test:	(c)	
% Loss, 1st 48 Hrs	0.0		Method		B
% Loss, 2nd 48 Hrs	0.2		Condition		Cast
Explosion in 100 Hrs	None		Confined		No
Flammability Index: Will not continue to burn			Density, gm/cc	1.66	
Hygroscopicity: %	<u>50/50</u>	<u>10/90</u>	Brisance, % TNT	121	
30°C, 90% RH	None	None			
Volatility:			Detonation Rate:		
			Confinement		None
			Condition		Cast
			Charge Diameter, in.	1.0	
			Density, gm/cc	1.66	
			Rate, meters/second	7465	

Pentolite, 50/50; 10/40

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<b>Booster Sensitivity Test:</b> (d) <u>50/50</u> Condition      Pressed      Cast Tetryl, gm      100      100 Wax, in. for 50% Detonation      2.36      2.08 Wax, gm Density, gm/cc      1.60      1.65	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z 'sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
<b>Heat of:</b> Combustion, cal/gm Explosion, cal/gm      1220 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	<b>Armor Plate Impact Test:</b> <u>50/50</u>  <b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec      170 Aluminum Fineness
<b>Specific Heat:</b> cal/gm/°C	<b>500-lb General Purpose Bomb:</b>  Plate Thickness, inches 1 1½ 1¾ 2½
<b>Burning Rate:</b> cm/sec	<b>Bomb Drop Test:</b>  <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b> Max Safe Drop, ft
<b>Thermal Conductivity:</b> cal/sec/cm/°C	<b>500-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Coefficient of Expansion:</b> Linear, %/°C  Volume, %/°C	<b>1000-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Hardness, Mohs' Scale:</b>	
<b>Young's Modulus:</b> E', dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc	
<b>Compressive Strength:</b> lb/inch <sup>2</sup> 2000-2200 Density, gm/cc      1.65	
<b>Vapor Pressure:</b> °C      mm Mercury	

<b>Fragmentation Test:</b>	<u>50/50</u>	<b>Shaped Charge Effectiveness, TNT = 100:</b>
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<u>50/50</u> <u>10/90</u> <u>50/50</u> <u>25/75</u> Glass Cones (?) Steel Cones (g)
Density, gm/cc	1.65	Hole Volume 157 105 149 119
Charge Wt, lb	2.147	Hole Depth 116 116 131 119
<b>Total No. of Fragments:</b>		<b>Color:</b> Yellow-white
For TNT	703	
For Subject HE	968	
<b>3 inch HE, M12A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b> Shaped charges, bursting charges, demolition blocks
Density, gm/cc	1.65	
Charge Wt, lb	0.872	
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Cast
For TNT	514	
For Subject HE	650	
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b> <u>50/50</u> <u>10/90</u> 1.65 1.60
At 9 ft	2810	
At 25½ ft	2580	
Density, gm/cc	1.66	
<b>Blast (Relative to TNT):</b>	(e)	<b>Storage:</b>
Air:		Method Dry
Peak Pressure	105	Hazard Class (Quantity-Distance) Class 9
Impulse	107	Compatibility Group Group I
Energy	--	Exudation
Air, Confined:		<b>Compatibility with Metals:</b>
Impulse		Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium or nickel are not affected. Zinc plated steel is only slightly affected.
Under Water:		Wet: Stainless steel, aluminum and mild steel coated with acid-proof black paint are not affected. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with copper, cadmium, zinc or nickel are slightly affected.
Peak Pressure		
Impulse		
Energy		
Underground:		<b>Effect of Temperature on</b> (h)
Peak Pressure		<b>Rate of Detonation:</b> <u>50/50</u>
Impulse		16 hrs at, °C -54 21
Energy		Density, gm/cc 1.67 1.66
<b>Eutectic Temperature, °C:</b>	76	Rate, m/sec 7470 7440
gm PETN/100 gm TNT		
76°C	13.0	
95°C	28.3	

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In coprecipitation, PETN and TNT are dissolved separately in acetone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PETN/TNT mixture being the more important for bursting charges and booster-surround charges.

References:<sup>56</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10, 303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.
- (h) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.

- (i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

0	1	2	3	4	5	6	7	8
1360	1291	1212	1133	1284	1325	1436	1477	1388
1420	1451	1262	1193	2004		1466	1677	1598
1570	1651	1372	1213			1796	1737	1668
			1363					1838

<sup>56</sup>See footnote 1, page 10.

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PETN (Pentaerythritol Tetranitrate)

<b>Composition:</b> %	<chem>O=[N+]([O-])C[C@H](C(=O)N([O-])[O-])[C@H](C(=O)N([O-])[O-])C=C</chem>	<b>Molecular Weight:</b> (C <sub>5</sub> H <sub>8</sub> N <sub>4</sub> O <sub>12</sub> )	316
C 19.0	ONO <sub>2</sub>	Oxygen Balance: CO <sub>2</sub> %	-10
H 2.5	CH <sub>2</sub>	CO %	15
N 17.7	O <sub>2</sub> NO—CH <sub>2</sub> —C—CH <sub>2</sub> —ONO <sub>2</sub>	<b>Density:</b> gm/cc	Crystal 1.77
O 60.8	CH <sub>2</sub>	<b>Melting Point:</b> °C	141
C/H Ratio 0.134	ONO <sub>2</sub>	<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point:</b> °C	
Bureau of Mines Apparatus, cm	17		
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.	6	<b>Refractive Index, n<sub>d</sub><sup>20</sup></b>	
Sample Wt, mg	16	n <sub>d<sub>20</sub></sub> n <sub>d<sub>25</sub></sub> n <sub>d<sub>30</sub></sub>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Crackles	cc/40 Hrs, at	
Filter Shoe	Unaffected	90°C	
<b>Rifle Bullet Impact Test: 5 Trials *</b>	%	100°C	0.5
Explosions	100	120°C	11+
Partials	0	135°C	
Burned	0	150°C	
Unaffected	0	<b>200 Gram Bomb Sand Test:</b>	
*4.00% moisture in samples.		Sand, gm	62.7
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	272	Minimum Detonating Charge, gm	
1	244	Mercury Fulminate	0.17*
5 Decomposes	225	Lead Azide	0.03*
10	211	Tetryl	--
15	--	*Alternative initiating charges.	
20	--	<b>Ballistic Mortar, % TNT:</b> (a)	145
<b>75°C International Heat Test:</b>		<b>Trouxi Test, % TNT:</b> (b)	173
% Loss in 48 Hrs	0.02	<b>Plate Lens Test:</b> (c)	
<b>100°C Heat Test:</b>		Method	A
% Loss, 1st 48 Hrs	0.1	Condition	Pressed
% Loss, 2nd 48 Hrs	0.0	Confined	Yes
Explosion in 100 Hrs	None	Density, gm/cc	1.50
<b>Flammability Index:</b> Will not continue to burn		Brisance, % TNT	129
<b>Hygroscopicity:</b> % 30°C, 90% RH	0.0	<b>Detonation Rate:</b>	
<b>Volatility:</b>	0.0	Confinement	None
		Condition	Pressed
		Charge Diameter, in.	1.00
		Density, gm/cc	1.70
		Rate, meters/second	8300

PETN (Pentaerythritol Tetranitrate)

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<b>Booster Sensitivity Test:</b>	(c)	<b>Decomposition Equation:</b>	(e)	(e)	(f)
Condition	Pressed	Oxygen, atoms/sec	$10^{19.8}$	$10^{20.6}$	$10^{23.1}$
Tetryl, gm	5	(Z/sec)			
Wax, in. for 50% Detonation		Heat, kilocalories/mole	47.0	50.9	52.3
Wax, gm	3	(ΔH, kcal/mol)			
Density, gm/cc	1.6	Temperature Range, °C	161-233	108-120	137-157
		Phase	Liquid	Solid	At melting point
<b>Heat of:</b>					
Combustion, cal/gm	1960				
Explosion, cal/gm	1385				
Gas Volume, cc/gm	790				
Formation, cal/gm	383				
Fusion, cal/gm					
<b>Specific Heat:</b> cal/gm/°C	(d)				
Room Temperature	0.26				
<b>Burning Rate:</b>					
cm/sec					
<b>Thermal Conductivity:</b>					
cal/sec/cm/°C					
<b>Coefficient of Expansion:</b>					
Linear, %/°C					
Volume, %/°C					
<b>Hardness, Mohs' Scale:</b>	1.9				
<b>Young's Modulus:</b>					
E', dynes/cm <sup>2</sup>					
E, lb/inch <sup>2</sup>					
Density, gm/cc					
<b>Compressive Strength:</b> lb/inch <sup>2</sup>					
Vapor Pressure:					
°C	mm Mercury				

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PETN (Pentaerythritol Tetranitrate)

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments:</p> <p>For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> White</p> <p><b>Principal Uses:</b></p> <p>Class A - Detonating fuse and boosters Class B - Priming compositions</p> <p><b>Method of Loading:</b></p>	Glass Cones	Steel Cones	Hole Volume		Hole Depth							
Glass Cones	Steel Cones												
Hole Volume													
Hole Depth													
<p><b>Fragment Velocity:</b> ft/sec</p> <p>At 9 ft At 25½ ft</p> <p>Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc      <math>\text{psi} \times 10^3</math></p> <table border="1"> <thead> <tr> <th>3</th> <th>5</th> <th>10</th> <th>20</th> <th>30</th> <th>40</th> </tr> </thead> <tbody> <tr> <td>1.37</td> <td>1.58</td> <td>1.64</td> <td>1.71</td> <td>1.73</td> <td>1.74</td> </tr> </tbody> </table> <p><b>Storage:</b></p>	3	5	10	20	30	40	1.37	1.58	1.64	1.71	1.73	1.74
3	5	10	20	30	40								
1.37	1.58	1.64	1.71	1.73	1.74								
<p><b>Blast (Relative to TNT):</b></p> <p>Air:</p> <p>Peak Pressure Impulse Energy</p> <p>Air, Confined:</p> <p>Impulse</p> <p>Under Water:</p> <p>Peak Pressure Impulse Energy</p> <p>Underground:</p> <p>Peak Pressure Impulse Energy</p>	<p><b>Hazard Class (Quantity-Distance):</b> Class 9</p> <p><b>Compatibility Group:</b> Group M (wet)</p> <p><b>Exudation:</b> None</p> <p><b>Bulk Modulus at Room Temperature (25°-30°C):</b> (1)</p> <table border="1"> <thead> <tr> <th>Dynes/cm<sup>2</sup> × 10<sup>-10</sup></th> <th>Density, gm/cc</th> </tr> </thead> <tbody> <tr> <td>4.60</td> <td>1.77</td> </tr> </tbody> </table>	Dynes/cm <sup>2</sup> × 10 <sup>-10</sup>	Density, gm/cc	4.60	1.77								
Dynes/cm <sup>2</sup> × 10 <sup>-10</sup>	Density, gm/cc												
4.60	1.77												

PETN (Pentaerythritol Tetranitrate)

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Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, Joules; Through 100 Mesh: (g)

Unconfined	0.06
Confined	0.21

Solubility, grams of PETN per 100 grams (%): (h)

<u>Trichlorethyrene or Alcohol</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.070	0	14.37	0	0.150	0	0.150
20	0.195	20	24.95	20	0.450	20	0.430
40	0.415	40	30.56	40	1.160	40	0.620
60	1.205	60	42.68	80	7.900	60	2.490
				80	5.850		
				100	15.320		
				112	30.900		

<u>Methyl acetate</u>		<u>Ether</u>		<u>-Ethoxy-ethyl-acetate</u>		<u>Chlorobenzene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	13	0	0.200	20	1.5	20	0.35
30	17	20	0.340	30	4.1	30	2.8
40	22	34.7	0.450	40	7.6	40	6.1
50	31			50	11.2	50	9.2
				60	14.2	60	12.2

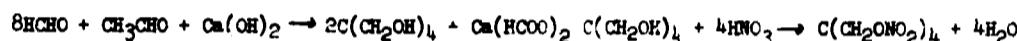
<u>Ethylenedichloride</u>		<u>Methanol</u>		<u>Tetrachloroethane</u>		<u>Carbon tetrachloride</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
10	0.9	20	0.46	20	0.18	20	0.096
30	1.5	40	1.15	30	0.27	30	0.108
50	2.6	60	2.6	40	0.40	40	0.118
				50	0.58	50	0.121

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PETN (Pentaerythritol Tetranitrate)

<u>Isopropanol</u>		<u>Isobutane</u>		<u>Chloroform</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
15	0.02	20	0.27	20	0.09	80	19.3
20	0.04	30	0.31			85	25.0
30	0.15	40	0.39			90	32.1
40	0.36	50	0.52			95	39.5
50	0.46					100	48.6
						105	58.2
						110	70.0
						115	87.5
						120	115
						125	161

Eutectic of the system PETN-TNT is about 13% PETN  
and 87% TNT at 76°C.

Preparation:(Nitroglycerin and Nitroglycerin Explosives, Naum)

1. In this preparation 1940 gm of formaldehyde and 600 gm of acetylaldehyde are dissolved in 90 liters of water containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with oxalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaerythritol, melting point 235°-240°C are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good agitation. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent 81,664 (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw 11, 112, 102 (1916) and 24, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PETN is decomposed by dissolving in 8 times its weight of technical grade acetone and burning the solution in a shallow container. If preferred, warm the acetone solution to 40°C, stir and add 7 parts by weight, to each part of PETN, of a solution of 1 part sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) in 2 parts water heated to 80°C. The aqueous solution should be added at such a rate that the acetone solution does not boil. After mixing is complete continue stirring for one-half hour.

PETN (Pentaerythritol Tetranitrate)

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References:<sup>57</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Test; Performance Tests. OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Naoum, Z ges Schiess - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) International Critical Tables.
- (e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.
- (f) A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglycerin, Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).
- (g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (h) Various sources in the open literature.
- (i) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.

(J) Also see the following Picatinny Arsenal Technical Reports on PETN:

0	1	2	3	4	5	6	7	8	9
760	1041	772	843	904	1305	1246	407	318	1379
1170	1311	922	863	1274	1525	1276	527	633	1429
1260	1381	1182	1063	1284	1445	1316	857	1238	1489
1290	1451	1192	1133	1414	1705	1376	1247	1318	1559
1300	1561	1212	1253		1885	1446	1517	1388	2179
1320	1611	1262	1343		2125	1456	1617	1568	
1360	1651	1342	1493			1466	1737	1558	
1380		1352	1533			1556	1797	1830	
1390		1372				1796		2178	
1430		1452							
1450									
1570									

<sup>57</sup>See footnote 1, page 16.

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Picramide (TNA) (2,4,6-Trinitroaniline)

<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>4</sub> N <sub>4</sub> O <sub>6</sub> )	228
C 31.5	Oxygen Balance:	-56
H 1.8	CO <sub>2</sub> %	-14
N 24.5	Density: gm/cc	Crystal 1.76
O 42.2	Melting Point: °C	189 to 190
C/H Ratio 0.500	Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg	Boiling Point: °C	Decomposes before boiling point
Picatinny Arsenal Apparatus, in. Sample Wt, mg	Refractive Index, n <sub>D<sup>20</sup></sub>	
23 20	n <sub>D<sup>25</sup></sub>	
	n <sub>D<sup>30</sup></sub>	
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
	90°C	----
	100°C	0.9
	120°C	
	135°C	
	150°C	
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partic's Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm	48.1
1 5 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm	
	Mercury Fulminate	----
	Lead Azide	0.30
	Tetryl	----
	<b>Ballistic Mortar, % TNT:</b>	100
	<b>Treuzi Test, % TNT:</b>	107
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Plate Dent Test:</b> Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
<b>Flammability Index:</b>	<b>Detonation Rate:</b>	
<b>Hygroscopicity:</b> %	Confinement	None
<b>Volatility:</b>	Condition	Pressed
	Charge Diameter, in.	0.5
	Density, gm/cc	1.72
	Rate, meters/second	7300

Picramide (TNA) (2,4,6-Trinitroaniline)

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b> Yellow	
For TNT		<b>Principal Uses:</b> High temperature heat resistant explosive	
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Method of Loading:</b> Pressed	
Density, gm/cc		<b>Loading Density:</b> gm/cc	
Charge Wt, lb		At 50,000 psi 1.72	
<b>Total No. of Fragments:</b>		<b>Storage:</b>	
For TNT		Method Dry	
For Subject HE		Hazard Class (Quantity-Distance) Class 9	
<b>Fragment Velocity: ft/sec</b>		Compatibility Group Group I	
At 9 ft		Exudation None	
At 25½ ft			
Density, gm/cc		<b>Solubility:</b>	
<b>Blast (Relative to TNT):</b>		Insoluble in water, slightly soluble in alcohol and ether. Soluble in hot glacial acetic acid, hot ethyl acetate and in benzene and acetone.	
<b>Air:</b>		<b>Heat of:</b>	
Peak Pressure		Combustion, cal/gm (a) 2962	
Impulse		Explosion, cal/gm 564	
Energy		Formation, cal/gm (a) 131	
<b>Air, Confined:</b>			
Impulse			
<b>Under Water:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Underground:</b>			
Peak Pressure			
Impulse			
Energy			

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Picramide (TNA) (2,4,6-Trinitroaniline)

Preparation:

Five grams of picryl chloride were dissolved in 180 milliliters of absolute methanol. The solution was then saturated with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 76% yield (3.6 gm) melting at 190°C (literature MP 189°C).

Origin:

Picramide (2,4 o-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with ammonium carbonate (CR 39, 853). The use of picramide, as a brisant explosive, was patented by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reacted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H<sub>2</sub>SO<sub>4</sub> at about 5°C with concentrated HNO<sub>3</sub> (Ber 41, 3091 (1908)). Holleman gives details of the preparation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference:<sup>58</sup>

- (a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

<sup>58</sup>See footnote 1, pag 10.

<b>Composition:</b>	<b>Molecular Weight:</b> 290	
%		
Explosive D	52	Oxygen Balance: CO <sub>2</sub> % -6.5
TNT	48	CO % -19
C/H Ratio		<b>Density:</b> gm/cc Cast 1.62
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Melting Point:</b> °C
Bureau of Mines Apparatus, cm	100+	<b>Freezing Point:</b> °C
Sample Wt 20 mg		<b>Boiling Point:</b> °C
Picatinny Arsenal Apparatus, in.	17	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b>
Sample Wt, mg	19	n <sub>25</sub> <sup>D</sup>
		n <sub>30</sub> <sup>D</sup>
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>
Steel Shoe	Unaffected	cc/10 Hrs, L:
Fiber Shoe	Unaffected	90°C
<b>Rifle Bullet Impact Test:</b>	Trials	100°C 0.37
	%	120°C 0.68
Explosions	0	135°C --
Partials	0	150°C 0.7
Burned	40	
Unaffected	60	<b>200 Gram Bomb Sand Test:</b>
		Sand, gm 45.0
<b>Explosion Temperature:</b>	°C	<b>Sensitivity to Initiators:</b>
Seconds, 0.1 (no cap used)	456	Minimum Detonating Charge, gm
1	354	Mercury Fulminate
5 Decomposes	285	Lead Azide 0.20
10	265	Tetryl 0.05
15	240	
20	255	<b>Ballistic Mortar, % TNT:</b> (%) 100
<b>75°C International Heat Test:</b>		<b>Troux Test, % TNT:</b>
% Loss in 48 Hrs	0.0	
<b>100°C Heat Test:</b>		<b>Plate Dent Test:</b> (%)
% Loss, 1st 48 Hrs	0.0	Method
% Loss, 2nd 48 Hrs	0.0	Condition 8.8%
Explosion in 100 Hrs	None	Confined 0.0
		Density, gm/cc 1.62
<b>Flammability Index:</b>		Briulance, % TNT 100
<b>Hygroscopicity:</b> % 30°C, 10% RH 0.02		
<b>Volatility:</b>		<b>Detonation Rate:</b> (%)
		Confinement 1.0
		Condition 8.8
		Charge Diameter, in 1.0
		Density, gm/cc 1.62
		Rate, meters/second 1.0

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc	1.61	Hole Volume	
Charge Wt, lb	2.075	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Brown-yellow	
For Subject HE	769	<b>Principal Uses:</b> AP, SAP projectiles and bombs	
<b>8 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Method of Loading:</b>	
Density, gm/cc	1.61	Cast	
Charge Wt, lb	0.850	<b>Loading Density:</b> gm/cc	
<b>Total No. of Fragments:</b>		1.62	
For TNT	514	<b>Storage:</b>	
For Subject HE	487	Dry	
<b>Fragment Velocity: ft/sec</b>		<b>Hazard Class (Quantity-Distance)</b>	
At 9 ft	2590	Class 9	
At 25½ ft	2320	<b>Compatibility Group</b>	
Density, gm/cc	1.62	Group I	
<b>Blast (Relative to TNT):</b>		<b>Exudation</b>	
Air:		None at 65°C	
Peak Pressure	100	<b>Preparation:</b>	
Impulse	100	Picratol is made by heating TNT to about 90°C in a steam-jacketed melt kettle. Explosive D is added slowly, without preheating, and the mixture stirred until uniform in composition. This slurry is cooled to about 85°C and poured into the appropriate ammunition component.	
Energy	--	<b>Origin:</b>	
Air, Confined:		Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler	
Impulse		<b>Booster Sensitivity Test:</b> (c)	
Under Water:		Condition	
Peak Pressure		Tetryl, gm	Cast
Impulse		Wax, in. for 50% Detonation	100
Energy		Density, gm/cc	1.00
<b>Underground:</b>		1.63	
Peak Pressure			
Impulse			
Energy			
<b>Bomb Drop Test:</b>			
T7, 2000-lb Semi-Armor-Piercing			
Bomb vs Concrete:			
Max Safe Drop, ft	10,000-12,000		

References: <sup>59</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10, 303, 15 June 1949.
- (d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
- (e) Also see the following Picatinny Arsenal Technical Reports on Picratol:

0	2	6	7	8	9
1470	1885	1466	1737	1838	1729
		1796	1797		
		1956			

<sup>59</sup>See footnote 1, page 10.

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Picric Acid

<b>Composition:</b>		<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>3</sub> N <sub>3</sub> O <sub>7</sub> ) 229
%		
C 31.5		
H 1.3		
N 18.3		
O 48.9		
C/H Ratio 0.656		
<b>Impact Sensitivity, 2 Kg Wt:</b>		
Bureau of Mines Apparatus, cm	85	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	13	
Sample Wt, mg	17	
<b>Friction Pendulum Test:</b>		
Steel Shoe		
Fiber Shoe		
<b>Rifle Bullet Impact Test:</b>	Trials	
	%	
Explosions	0	
Partials	60	
Burned	40	
Unaffected	0	
<b>Explosion Temperature:</b>	"C	
Seconds, 0.1 (no cap used)		
1		
5 Decomposes	320	
10		
15		
20		
<b>75°C International Heat Test:</b>		
% Loss in 48 Hrs	0.01	
<b>100°C Heat Test:</b>		
% Loss, 1st 48 Hrs	0.03	
% Loss, 2nd 48 Hrs	0.09	
Explosion in 100 Hrs	None	
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> % 30°C, 90% RH	0.0L	
<b>Volatility:</b>		
<b>Oxygen Balance:</b>		
CO <sub>2</sub> %	-2.5	
CO %	-3.5	
<b>Density:</b> gm/cc	Crystal	1.76
<b>Melting Point:</b> °C		122
<b>Freezing Point:</b> °C		
<b>Boiling Point:</b> °C		
<b>Refractive Index:</b> n <sub>20</sub> <sup>D</sup>		
n <sub>25</sub> <sup>D</sup>		
n <sub>30</sub> <sup>D</sup>		
<b>Vacuum Stability Test:</b>		
cc/40 H <sub>2</sub> , at		
°C		
100°C		0.2
120°C		0.5
135°C		
150°C		
<b>200 Gram Bomb Sand Test:</b>		
Sand, gm		48.5
<b>Sensitivity to Initiation:</b>		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.26*
Lead Azide		0.24*
Tetryl		
*Alternative initiating charges.		
<b>Ballistic Mortar, % TNT:</b>	(a)	112
<b>Treuzi Test, % TNT:</b>	(b)	101
<b>Plate Dent Test:</b>	(c)	
Method		A
Condition		Pressed
Confined		No
Density, gm/cc		1.50
Brisance, % TNT		107
<b>Detonation Rate:</b>	(d)	
Confinement		Unconfined
Condition	Pressed	Cas
Charge Diameter, in.	1.0	1.25
Density, gm /cc	1.4	1.71
Rate, meters/second	270	730

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<b>Booster Sensitivity Test:</b> (c)	Pressed	Cast	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z./sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
Condition			
Tetryl, gm	10	5	
Wax, in. for 50% Detonation			
Wax, gm	2	0	
Density, gm/cc	1.6	1.7	
<b>Heat of:</b>			<b>Armor Plate Impact Test:</b>
Combustion, cal/gm	2072		
Explosion, cal/gm	1000		<b>60 mm Mortar Projectile:</b> 50% Inert, Velocity, ft/sec
Gas Volume, cc/gm	675		Aluminum Fineness
Formation, cal/gm	245		
Fusion, cal/gm	20.4		<b>500-lb General Purpose Bombs:</b>
Temperature, °C	122		
<b>Specific Heat:</b> cal/gm/°C (e)			Plate Thickness, inches
0	0.235		1
30	0.258		1 1/4
60	0.282		1 1/2
90	0.310		1 3/4
120	0.337		
<b>Burning Rate:</b> cm/sec			<b>Bomb Drop Test:</b>
<b>Thermal Conductivity:</b> (f)			<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>
cal/sec/cm/°C	$6.2 \times 10^{-4}$		Max Safe Drop, ft
Density, gm/cc	1.406		
<b>Coefficient of Expansion:</b>			<b>500-lb General Purpose Bomb vs Concrete:</b>
Linear, %/°C			Height, ft
Volume, %/°C			Trials
<b>Hardness, Mohs' Scale:</b>	2.1		Unaffected
<b>Young's Modulus:</b>			Low Order
E', dynes/cm <sup>2</sup>			High Order
E, lb/inch <sup>2</sup>			
Density, gm/cc			<b>1000-lb General Purpose Bomb vs Concrete:</b>
<b>Compressive Strength:</b> lb/inch <sup>2</sup>			Height, ft
<b>Vapor Pressure:</b>			Trials
°C	mm Mercury		Unaffected
135	2		Low Order
255	50		High Order

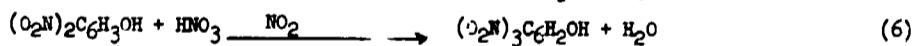
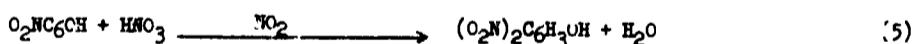
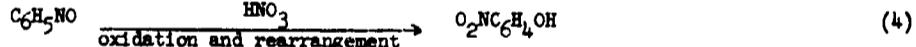
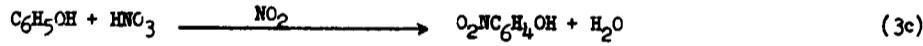
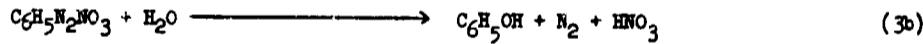
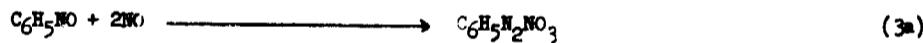
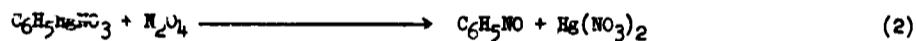
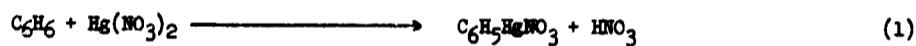
<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc Charge Wt, lb</p> <p>Total No. of Fragments: For TNT For Subject HE</p> <p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p> <p><b>Blast (Relative to TNT):</b></p> <p>Air: Peak Pressure Impulse Energy</p> <p>Air, Confined: Impulse</p> <p>Under Water: Peak Pressure Impulse Energy</p> <p>Underground: Peak Pressure Impulse Energy</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth								
Glass Cones	Steel Cones													
Hole Volume														
Hole Depth														
<table border="1"> <tbody> <tr> <td>Color:</td> <td>Yellow</td> </tr> <tr> <td>Principal Uses:</td> <td>Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D</td> </tr> <tr> <td>Method of Loading:</td> <td>Pressed</td> </tr> <tr> <td>Loading Density: gm/cc</td> <td>psi <math>\times 10^3</math></td> </tr> <tr> <td>3 1.40</td> <td>5 1.50</td> <td>10 1.57</td> <td>12 1.59</td> <td>15 1.61</td> <td>20 1.64</td> </tr> </tbody> </table>	Color:	Yellow	Principal Uses:	Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D	Method of Loading:	Pressed	Loading Density: gm/cc	psi $\times 10^3$	3 1.40	5 1.50	10 1.57	12 1.59	15 1.61	20 1.64
Color:	Yellow													
Principal Uses:	Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D													
Method of Loading:	Pressed													
Loading Density: gm/cc	psi $\times 10^3$													
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<p><b>Storage:</b></p> <table border="1"> <tbody> <tr> <td>Method:</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance):</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group:</td> <td>Group I</td> </tr> <tr> <td>Exudation:</td> <td>None</td> </tr> </tbody> </table>	Method:	Dry	Hazard Class (Quantity-Distance):	Class 9	Compatibility Group:	Group I	Exudation:	None						
Method:	Dry													
Hazard Class (Quantity-Distance):	Class 9													
Compatibility Group:	Group I													
Exudation:	None													

Picric Acid

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Solubility: grams per 100 grams (S) of: (g)

<u>Water</u>		<u>Alcohol</u>		<u>Benzene</u>		<u>Toluene</u>		<u>Ether</u>	
<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>
0	0.85	0	4.1	0	~2	20	~13	20	~3
20	1.17	20	5.9	20	9.6	60	~30	34.7	3.96
40	1.88	40	12.0	40	27.5				
60	2.98			60	59				
80	4.53								
100	7.1								
<u>Chloroform</u>		<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Pyridine</u>		<u>Acetone</u>	
<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>
20	~2	20	42	20	~0.07	10	24	20	125
60	~6	30	50	60	~0.4	30	37.5	30	137
		40	58			50	58	40	164
		50	69					50	208
<u>Methanol</u>		<u>Isopropyl alcohol</u>		<u>Propanol-1</u>		<u>Carbon disulfide</u>			
<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>	<u>°C</u>	<u>S</u>		
0	14	10	6.4	0	2.4	20	0.12		
20	19	30	9.8	20	3.3	30	0.16		
40	31	50	15.5	40	5.4				
50	41			50	7.4				

Preparation: (Summary Report of NIDRC, Div 8, Vol I)

The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the oxynitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the overall rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the oxynitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of oxynitration. The oxynitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of benzene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitro-phenols and amount of colored by-products. Saturation of the oxynitration solution with benzene is undesirable and thus in batch processes slow benzene addition is preferable to the addition of it in one portion; in continuous processes where an excess of benzene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a fairly wide range. Concentrations of 0.3 to 0.5 mole of mercuric nitrate per liter of oxynitration solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous solution process, works on the following cycle. The oxynitration solution is saturated with benzene by vigorous agitation with excess benzene at room temperature, the saturated solution is separated from excess benzene and circulated through a heated coil; it is then cooled to room temperature and agitated again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; 70 gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Wouiff who found the reaction of nitric acid and indigo yielded a dye. Haussmann isolated Picric Acid in 1778 and studied it further (*Journal de physique* 32, 165 (1780)). The preparation was studied by many chemists but in 1841 Laurent established its identity (*Ann chim phys* III, p. 221 (1841)). It was used as a yellow dye until Turpin, in 1865, proposed Picric Acid as a bursting charge for high explosive shell (French Patent 167,512). The British adopted Picric Acid as a military explosive in 1888 under the name of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TNT about 1900. Today Picric Acid is used for the manufacture of Explosive D.

Destruction by Chemical Decomposition:

Picric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide ( $\text{Na}_2\text{S}\cdot\text{9H}_2\text{O}$ ) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

References:<sup>60</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) International Critical Tables.
- (f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity Explosive Materials, AC Report No. 2861, First Report, August 1942.
- (g) Values taken from various sources in the open literature.

(h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

1	2	3	4	5	6	7	8	9
1651	132	1383	694	65	266	1347	1118	15.9
	582		764	425	556	1557		
	1172		874	1585	926			
	1352				976			
	1372				986			
					1446			
					1556			

<sup>60</sup>See Footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b>	310
PEIN	81	Oxygen Balance: CO <sub>2</sub> %	-74
Gulf Crown E Oil	19	CO %	-31
C/H Ratio		Density: gm/cc Hand tamped	1.35
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg		Melting Point: °C	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	11 27	Frosting Point: °C	
Friction Pendulum Test: Steel Shoe	Unaffected	Boiling Point: °C	
Fiber Shoe	Unaffected	Refractive Index, n <sub>20</sub>	n <sub>20</sub> n <sub>25</sub> n <sub>30</sub>
Rifle Bullet Impact Test: Trials	%	Vacuum Stability Test: cc/40 Hrs, at	
Explosions	0	90°C	
Partials	0	100°C	0.48
Burned	0	120°C 16 hours	11+
Unaffected	100	135°C	
		150°C	
Explosion Temperature: °C Seconds, 0.1 (no cap used)		200 Gram Bomb Sand Test: Sand, gm	41.6
1		Sensitivity to Initiation: Minimum Detonating Charge, gm	
5 Decomposes*		Mercury Fulminate	0.20*
10		Lead Azide	0.20*
15		Tetryl	
20		*Alternative initiating charges.	
*No value obtained.		Ballistic Meter, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Tensile Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs	0.17	Plate Dent Test: (a)	
% Loss, 2nd 48 Hrs	0.00	Method	B
Explosion in 100 Hrs	None	Condition	Hand tamped
Flammability Index:		Confined	No
Hygroscopicity: % 30°C, 90% RH	0.02	Density, gm/cc	1.33
Volatility:		Brisance, % TNT	76
		Detonation Rate:	
		Confinement	None
		Condition	Hand tamped
		Charge Diameter, in.	1.0
		Density, gm/cc	1.37
		Rate, meters/second	7075

## PIPE

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Gloss Cones	Steel Cones
Density, gm/cc	1.33	Hole Volume	
Charge Wt, lb	1.723	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703		
For Subject HE	519	<b>Principal Uses:</b> Plastic demolition explosive	
<b>3 inch HE, M42A1 Projectile, Lot KC-3:</b>			
Density, gm/cc	1.39		
Charge Wt, lb	0.735		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Hand tamped	
For TNT	514		
For Subject HE	428		
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/l.c.</b> 1.35	
At 9 ft			
At 25½ ft			
Density, gm/cc		<b>Storage:</b>	
<b>Blast (Relative to TNT):</b>		Method Dry	
Air:		Hazard Class (Quantity-Distance) Class 9	
Peak Pressure		Compatibility Group Group I	
Impulse		Exudation	
Energy			
Air, Confined:	Impulse	<b>Origin:</b>	
Under Water:		PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United States during World War II.	
Peak Pressure			
Impulse		<b>References:</b> 61	
Energy		(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests; Performance Tests</u> , OSRE Report No. 5746, 27 December 1945.	
Underground:			
Peak Pressure		(b) S. Livingston, <u>Properties of Explosives PIPE, PIPE and PEP-3</u> , Picatinny Arsenal Technical Report 1517, 24 April 1945.	
Impulse			
Energy			
<b>Preparation:</b>			
PIPE is manufactured by simple mechanical mixing of PETN in oil.			

61 See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b> 291
Lead Nitrate	70	<b>Oxygen Balance:</b> CO <sub>2</sub> % -5.4 CO % +9.3
TNT	30	<b>Density:</b> gm/cc
<b>C/H Ratio</b>		<b>Melting Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt.</b> Bureau of Mines Apparatus, cm	--	<b>Freezing Point:</b> °C
Sample Wt 20 mg		<b>Boiling Point:</b> °C
Picatinny Arsenal Apparatus, in.	13	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b>
Sample Wt, mg	22	n <sub>25</sub> <sup>D</sup>
		n <sub>35</sub> <sup>D</sup>
<b>Friction Pendulum Test:</b> Steel Shoe		<b>Vacuum Stability Test:</b> cc/40 Hrs, at
Fiber Shoe		90°C
<b>Rifle Bullet Impact Test:</b> Trials	%	100°C
Explosions		120°C
Partials		135°C
Burned		150°C
Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm 32.4
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm
1		Mercury Fulminate --
5 Decomposes	238	Lead Azide 0.20
10		Tetryl 0.10
15		
20		
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Ballistic Meter, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		<b>Traqz Test, % TNT:</b>
% Loss, 2nd 48 Hrs		<b>Plate Dent Test:</b>
Explosion in 100 Hrs		Method
<b>Flammability Index:</b>		Condition
<b>Hygroscopicity:</b> %		Confined
<b>Volatility:</b>		Density, gm/cc
		Brisance, % TNT
		<b>Detonation Rate:</b> (c) Confinement
		Condition
		Charge Diameter, in.
		Density, gm/cr. 2.89
		Rate, meters/second 4850

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M471 Projectile, Lot WC-91:		Glass Cones	Steel Cones (a)
Density, gm/cc		Hole Volume	114
Charge Wt, lb		Hole Depth	103
<b>Total No. of Fragments:</b>		<b>Color:</b> Light yellow	
For TNT			
For Subject HE			
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principal Uses:</b>	
Density, gm/cc			
Charge Wt, lb			
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Cast	
For TNT			
For Subject HE			
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		Method	Dry
Peak Pressure			
Impulse			
Energy			
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance):</b> Class 9	
Impulse			
<b>Under Water:</b>		<b>Compatibility Group:</b> Group I	
Peak Pressure			
Impulse			
Energy			
<b>Underground:</b>		<b>Exudation:</b>	
Peak Pressure			
Impulse			
Energy			
<b>Preparation:</b>		<b>Origin:</b>	
Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.		An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Margarite."	
		<b>References:</b> <sup>62</sup>	
		(a) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition</u> , NDRC Contract W-672-ORD-5723.	
		(b) <u>Earp's Dictionary of Applied Chemistry</u> , Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.	

<sup>62</sup>See footnote 1, page 10.

PLX (Liquid)

<b>Composition:</b> % Nitromethane 100 95 Ethylenediamine -- 5	<b>Molecular Weight:</b> $\frac{100}{61}$ $\frac{95/5}{61}$
*The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under <u>Storage</u> .	<b>Oxygen Balance:</b> CO, % -39 -48 CO, % -13 -21
	<b>Density:</b> gm/cc 1.14 1.12
	<b>Melting Point:</b> °C -29
	<b>Freezing Point:</b> °C
	<b>Boiling Point:</b> °C 101
	<b>Refractive Index:</b> $n_{D}^{20}$ $n_{D}^{25}$ $n_{D}^{20}$
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
	<b>200 Gram Bomb Sand Test:</b> $\frac{100}{8.1}$ $\frac{95/5}{50.6}$ Sand, gm
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Sensitivity to Ignition:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
<b>Rifle Bullet Impact Test:</b> 10 Trials 5 Trials Explosions % 0 0 Partials 0 0 Burned 0 0 Unaffected 100 100	<b>Ballistic Meter, % TNT:</b> 134
<b>Explosion Temperature:</b> °C Seconds, 0.1 $\frac{100}{1}$ $\frac{95/5}{5}$ 1 5 430 430 10 15 20	<b>Treitz Test, % PA:</b> 127
<b>75°C Intertempered Heat Test:</b> % Loss in 48 Hrs	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Detonation Rate:</b> $1/32''^*$ $1/32''^*$ Confinement Glass Glass Condition Liquid Liquid Charge Diameter, in. 1.25 0.94 Density, gm/cc 1.14 1.12 Rate, meters/second 6210 6165 *Tube wall thickness
<b>Flammability Index:</b>	
<b>Hygrosopicity:</b> %	
<b>Volatility:</b>	

PLX (Liquid)

AMCP 706-177

<b>Booster Sensitivity Test:</b>	<u>Kitromethane</u>	<b>Decomposition Equation:</b>	(d)	<u>Nitromethane</u>
Condition		Oxygen, atoms/sec		$10^{14.0}$
Tetryl, gm		(Z/sec)		
Wax, in. for 50% Detonation		Heat, kilocalorie/mole		56.0
Wax, gm		( $\Delta H$ , kcal/mol)		
Density, gm/cc		Temperature Range, °C		380-430
<b>Heat of:</b>		Phase		Gaseous
Combustion, cal/gm	(a) 2830			
Explosion, cal/gm				
Gas Volume, cc/gm				
Formation, cal/gm	-348			
Fusion, cal/gm				
Vaporization, cal/gm	149			
<b>Specific Heat:</b> cal/gm/°C (b)				
$C_p = 0.4209 - 0.00076t + 0.0000061t^2$ for 15°C to 70°C				
<b>Burning Rate:</b>		<b>Plate Thickness, inches</b>		
cm/sec		1		
		1½		
		1¾		
		2¼		
<b>Thermal Conductivity:</b>				
cal/sec/cm/°C				
<b>Coefficient of Expansion:</b>		<b>Ram Drop Test:</b>		
Linear, %/°C		<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>		
Volume, %/°C		Max Safe Drop, ft		
<b>Hardness, Mohs' Scale:</b>		<b>500-lb General Purpose Bomb vs Concrete:</b>		
<b>Young's Modulus:</b>		Height, ft		
E', dynes/cm²		Trials		
E, lb/inch²		Unaffected		
Density, gm/cc		Low Order		
<b>Compressive Strength:</b> lb/inch²		High Order		
<b>Vapor Pressure:</b>		<b>1000-lb General Purpose Bomb vs Concrete:</b>		
'C	mm Mercury	Height, ft		
70	258	Trials		
85	444	Unaffected		
		Low Order		
		High Order		

<b>Fragmentation Test:</b> <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot NC-5:</b> Density, gm/c.c. Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <table border="1"> <tr> <td><b>Color:</b></td> <td>Light yellow</td> </tr> </table> <table border="1"> <tr> <td><b>Principal Uses:</b></td> <td>Minefield clearing</td> </tr> </table> <table border="1"> <tr> <td><b>Method of Loading:</b></td> <td>Pumping</td> </tr> </table> <table border="1"> <tr> <td><b>Loading Density: gm/cc</b></td> <td>100 1.14</td> <td>95/5 1.12</td> </tr> </table> <table border="1"> <tr> <td><b>Storage:</b></td> <td></td> </tr> <tr> <td>Method</td> <td>Components stored separately; mixed only when ready to use</td> </tr> <tr> <td colspan="2"><b>Hazard Class (Quantity-Distance)</b></td></tr> <tr> <td colspan="2"><b>Compatibility Group</b></td></tr> <tr> <td colspan="2"><b>Exudation</b></td></tr> </table> <table border="1"> <tr> <td><b>Minimum Propagating Thickness, in:</b></td> <td>100 0.5</td> <td>95/5 0.063</td> </tr> </table> <table border="1"> <tr> <td><b>Viscosity, centipoises:</b></td> <td>(*)</td> </tr> <tr> <td>Temp., 10°C</td> <td>0.748</td> </tr> <tr> <td>25°C</td> <td>0.625</td> </tr> <tr> <td>40°C</td> <td>0.533</td> </tr> </table> <table border="1"> <tr> <td colspan="3"><b>Compatibility with Metals:</b></td></tr> <tr> <td colspan="3">Stainless steel, mild steel and duriron not affected; corrodes brass.</td></tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth		<b>Color:</b>	Light yellow	<b>Principal Uses:</b>	Minefield clearing	<b>Method of Loading:</b>	Pumping	<b>Loading Density: gm/cc</b>	100 1.14	95/5 1.12	<b>Storage:</b>		Method	Components stored separately; mixed only when ready to use	<b>Hazard Class (Quantity-Distance)</b>		<b>Compatibility Group</b>		<b>Exudation</b>		<b>Minimum Propagating Thickness, in:</b>	100 0.5	95/5 0.063	<b>Viscosity, centipoises:</b>	(*)	Temp., 10°C	0.748	25°C	0.625	40°C	0.533	<b>Compatibility with Metals:</b>			Stainless steel, mild steel and duriron not affected; corrodes brass.		
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PLX (Liquid)Origin:

Nitromethane has been known since 1872 (Kolbe, J. prakt Chem (2) 5, 427 (1872)), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethane produced as a by-product of the nitration of propane (U. S. Patent 1,967,667 (1934); British Patent 3,707 (1937); and Canadian Patent 371,007 (1938)).

The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of detonation by the addition of various amines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine showed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Bowen, PATR No. 1965, 17 September 1945).

References:<sup>63</sup>

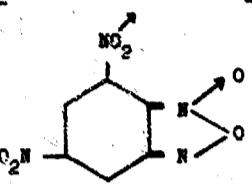
- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," Ind Engr Chem 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).
- (c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).
- (d) T. L. Cottrell, T. E. Graham and T. J. Reid, "The Thermal Decomposition of Nitromethanes," Transactions of the Faraday Society 47, 584 (1951).
- (e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bill, "Chemical Propellants: Stability of Mononitromethane," Ind Engr Chem 40, 1320 (1948).
- (f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

<u>0</u>	<u>1</u>	<u>3</u>	<u>2</u>	<u>6</u>	<u>I</u>	<u>8</u>	<u>2</u>
1660	1681	2113	1565	2016	1747	1708	1619
	1831						

<sup>63</sup>See footnote 1, page 10.

AMCP 706-177

Potassium Dinitrobenzofuroxan (KDNBF)

<b>Composition:</b> % C 27.3 H 0.4 N 21.2 O 36.3 K 14.8		<b>Molecular Weight:</b> (KC6H4N4O6) 225
<b>C/H Ratio</b> 0.416		<b>Oxygen Balance:</b> CO, % -60 CO % -18
<b>Impact Sensitivity, 2 Kg Wh:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 lb wt) 6 Sample Wt, mg 7		<b>Density:</b> gm/cc 2.21
<b>FriCTION Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe Explodes		<b>Melting Point:</b> °C Explodes 210
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected		<b>Freezing Point:</b> °C
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 250 10 -- 15 -- 20 --		<b>Selling Point:</b> °C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Refractive Index:</b> nD <sub>20</sub> nD <sub>25</sub> nD <sub>30</sub>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Flammability Index:</b>		<b>200 Gram Bomb Sand Test:</b> Sand, gm 44.8 43.6 Black powder fuse 9.5
<b>Hypersensitivity:</b> % 30°C, 75% RH 0.11 30°C, 90% RH 0.27		<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm:</b> Mercury Fulminate 0.30 0.20 Lead Azide 0.10 Tetryl
<b>Volatility:</b>		<b>Ballistic Mortar, % TNT:</b> <b>Trend Test, % TNT:</b>
		<b>Plate Blast Test:</b> Method Condition Confined Density, gm/cc Briance, % TNT
		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

Potassium Dinitrobenzofuran (KDNP)

AMCP 706-177

Booster Sensitivity Test:		Decomposition Equation:	
Condition		Oxygen, atoms/sec	
Tetryl, gm		(Z/sec)	
Wax, in. for 50% Detonation		Heat, kilocalories/mole	
Wax, gm		(AH, kcal/mol)	
Density, gm/cc		Temperature Range, °C	
Heat of:		Phase	
Combustion, cal/gm	2209		
Explosion, cal/gm	725		
Gas Volume, cc/gm	604		
Formation, cal/gm			
Fusion, cal/gm			
Specific Heat: cal/gm/°C (b)		Armor Plate Impact Test:	
$^{\circ}\text{C}$		60 mm Mortar Projectile:	
-50	0.217	50% Inert, Velocity, ft/sec	
0	0.217	Aluminum Fineness	
25	0.217		
50	0.217		
Burning Rate: cm/sec		500-lb General Purpose Bomb:	
Thermal Conductivity: cal/sec/cm/°C		Plate Thickness, inches	
Coefficient of Expansion: Linear, %/°C		1	
Volume, %/°C		1½	
Hardness, Mohs' Scale:		1½	
Young's Modulus:		1%	
E', dynes/cm²			
E, lb/inch²			
Density, gm/cc			
Compressive Strength: lb/inch²		Bomb Drop Test:	
Vapor Pressure: mm Mercury		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:	
		Max Safe Drop, ft	
		500-lb General Purpose Bomb vs Concrete:	
		Height, ft	
		Trials	
		Unaffected	
		Low Order	
		High Order	
1000-lb General Purpose Bomb vs Concrete:			
		Height, ft	
		Trials	
		Unaffected	
		Low Order	
		High Order	

ALICP 706-177

Potassium Dinitrobenzofuroxan (KDNEF)

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb		<b>Shaped Charge Effectiveness, TNT = 100:</b> Glass Cones      Steel Cones Hole Volume Hole Depth																													
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Color:</b> Orange to brown																													
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb		<b>Principal Uses:</b> Primary explosive																													
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Method of Loading:</b> Pressed																													
<b>Fragment Velocity: ft/sec.</b> At 9 ft At 25½ ft Density, gm/cc		<b>Loading Density: gm/cc</b> <b>psi x 10<sup>3</sup></b> 10      20      30      40      80 1.63      1.77      1.81      1.86      1.98																													
<b>Blast (Relative to TNT):</b> Air: Peak Pressure Impulse Energy		<b>Storage:</b> Method      Wet Hazard Class (Quantity-Distance)      Class 9 Compatibility Group      Group M (wet) Exudation																													
Air, Confined: Impulse		<b>Solubility in Wat., gm/100 gm solvent, at:</b> 30°C      0.245																													
Under Water: Peak Pressure Impulse Energy		<b>Stab Sensitivity:</b> <table border="1"> <thead> <tr> <th>Density gm/cc</th> <th>0%</th> <th>50%</th> <th>100%</th> </tr> </thead> <tbody> <tr> <td>1.63</td> <td>73</td> <td>79</td> <td>84</td> </tr> <tr> <td>1.77</td> <td>66</td> <td>75</td> <td>83</td> </tr> <tr> <td>1.81</td> <td>42</td> <td>48</td> <td>64</td> </tr> <tr> <td>1.86</td> <td>12</td> <td>15</td> <td>18</td> </tr> <tr> <td>1.93</td> <td>11</td> <td>17</td> <td>21</td> </tr> <tr> <td>1.98</td> <td>7</td> <td>11</td> <td>14</td> </tr> </tbody> </table>		Density gm/cc	0%	50%	100%	1.63	73	79	84	1.77	66	75	83	1.81	42	48	64	1.86	12	15	18	1.93	11	17	21	1.98	7	11	14
Density gm/cc	0%	50%	100%																												
1.63	73	79	84																												
1.77	66	75	83																												
1.81	42	48	64																												
1.86	12	15	18																												
1.93	11	17	21																												
1.98	7	11	14																												
Underground: Peak Pressure Impulse Energy		<b>Activation Energy:</b> kcal/mol      82.6 Induction Period, sec      0.5-10																													

Potassium Dinitrobenzofuran (KDNEF)

AMCP 706-177

Preparation of Potassium Salt of 4,6-dinitrobenzofuran: (a)

Benzofuran, made by the reaction of ortho-nitroaniline and alkaline sodium hypochlorite, was dissolved in 5 parts of 96% sulfuric acid and nitrated at 5°-20°C with a 4 to 1 sulfuric-nitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobenzofuran with potassium bicarbonate, followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210°C.

Origin:

The potassium salt of 4,6-dinitrobenzofuran was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: <sup>64</sup>

(a) R. J. Gaughan, J. P. Picard and J. V. R. Kaufman, "Contribution to the Chemistry of Benzofuran Derivatives," J Am Chem Soc 76, 2233 (1954).

(b) C. Leachitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.

(c) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitrobenzofuran:

2	3	6	2
2.22	2093	2146	2179

<sup>64</sup>See footnote 1, page 10.

<b>Composition:</b>		<b>Molecular Weight:</b>	252
%			
RDX	30	Oxidation:	-45 -9
Tetryl	50		
TNT	20	Density: gm/cc	1.68
C/H Ratio			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	44	Melting Point: °C	Eutectic 67
Sample Wt 20 mg		Freezing Point: °C	
Picatinny Arsenal Apparatus, in.		Boiling Point: °C	
Sample Wt, mg		Refractive Index, $n_{D}^{20}$	$n_{D}^{20}$ $n_{D}^{25}$ $n_{D}^{28}$
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test: Trials		100°C	3.0
	%	120°C	
Explosions	20	135°C	
Partials	20	150°C	
Burned	0		
Unaffected	60	200 Gram Bomb Stand Test:	
		Sand, gm	54.8
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.23*
5		Lead Azide	0.22*
10		Tetryl	
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT: (a)	132
75°C International Heat Test:		Trend Test, % TNT:	
% Loss in 48 Hrs			
100°C Heat Test:		Plate Dent Test: (b)	
% Loss, 1st 48 Hrs		Method	B
% Loss, 2nd 48 Hrs		Condition	Cast
Explosion in 100 Hrs		Confined	No
		Density, gm/cc	1.68
Plasticity Index:		Brisance, % TNT	127
Hygrosensitivity: % 30°C, 90% RH, 15 days	0.00		
Volatility:		Detonation Rate:	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.64
		Rate, meters/second	7655

<u>Fragmentation Test:</u>		<u>Shaped Charge Effectiveness, TNT = 100:</u>	
<u>90 mm HE, M71 Projectile, Lot WC-91:</u>		<u>Glass Cones      Steel Cones</u>	
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
<u>Total No. of Fragments:</u>			
For TNT		703	
For Subject HE		999	
<u>3 inch HE, M43A1 Projectile, Lot KC-5:</u>		<u>Principal Uses: Land mines and demolition charges</u>	
Density, gm/cc		1.63	
Charge Wt, lb		0.864	
<u>Total No. of Fragments:</u>			
For TNT		514	
For Subject HE		685	
<u>Fragment Velocity: ft/sec</u>		<u>Method of Loading:</u>	
At 9 ft		2690	
At 25½ ft		2460	
Density, gm/cc		1.64	
<u>Blast (Relative to TNT):</u>		<u>Cast</u>	
<u>Air:</u>		<u>1.68</u>	
Peak Pressure		(d)	
Impulse		111	
Energy		109	
<u>Air, Confined:</u>		--	
<u>Under Water:</u>		<u>Storage:</u>	
Peak Pressure		Method	
Impulse		Dry	
Energy		Hazard Class (Quantity-Distance)	
<u>Underground:</u>		Class 9	
Peak Pressure		Compatibility Group	
Impulse		Group I	
Energy		Exudation	
<u>Booster Sensitivity Test:</u>		Exudes at 65°C	
<u>(c)</u>		<u>Preparation:</u>	
Condition		RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetrytol (40/60) previously melted in a steam-jacketed melt kettle.	
Tetryl, gm		Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition.	
Wax, in. for 50% Detonation		PTX-1 is also prepared by adding tetryl to RDX Composition B.	
Density, gm/cc		Compatibility with Metals:	
1.94		Dry: Aluminum, mild steel not affected.	
1.61		Wet: Aluminum, mild steel not affected.	

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high explosive rounds (PAIR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/tetryl/TNT, designated PTX-1 was developed which had explosive and physical properties offering considerable advantage for military applications (PAIR No. 1350, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65°C without emulsion.

References:<sup>65</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 503, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

0	2	3	6	I	2
1530	1402	1623	1466	1437	1379
			1506		1429
					1469

<sup>65</sup>See footnote 1, page 10.

<p><b>Composition:</b> %</p> <table> <tr><td>RDX</td><td>44</td><td>-</td><td>41</td></tr> <tr><td>PEIN</td><td>26</td><td>-</td><td>26</td></tr> <tr><td>TNT</td><td>26</td><td>-</td><td>33</td></tr> <tr><td colspan="4"><b>C/H Ratio</b></td></tr> </table> <p><b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm      35 Sample Wt 20 mg</p> <p><b>Picatinny Arsenal Apparatus, in.</b> Sample Wt, mg</p>	RDX	44	-	41	PEIN	26	-	26	TNT	26	-	33	<b>C/H Ratio</b>				<p><b>Molecular Weight:</b> 244      243</p> <p><b>Oxygen Balance:</b> CO<sub>2</sub> %      -33      -36 CO %      -3      -4</p> <p><b>Density:</b> gm/cc      1.70</p> <p><b>Melting Point:</b> °C      Eutectic      75</p> <p><b>Freezing Point:</b> °C</p> <p><b>Boiling Point:</b> °C</p> <p><b>Refractive Index:</b> n<sub>D<sup>20</sup></sub> n<sub>D<sup>25</sup></sub> n<sub>D<sup>30</sup></sub></p>
RDX	44	-	41														
PEIN	26	-	26														
TNT	26	-	33														
<b>C/H Ratio</b>																	

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	1.68	Hole Volume ~ 130	
Charge Wt, lb	2.226	Hole Depth	
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703		
For Subject HE	1128		
<b>3 inch HE, M42A1 Projectile, Lot KC-8:</b>		<b>Principal Uses:</b> Shaped charges Fragmentation charges	
Density, gm/cc	1.70		
Charge Wt, lb	0.897		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b> Cast	
For TNT	514		
For Subject HE	750	<b>Loading Density:</b> gm/cc 1.70	
<b>Fragment Velocity: ft/sec</b>		<b>Storage:</b>	
At 9 ft	3020	Method	
At 25½ ft	2850	Hazard Class (Quantity-Distance)	
Density, gm/cc	1.70	Class 9	
<b>Effect (Relative to TNT):</b>		<b>Compatibility Group:</b> Group I	
Air:	(a)	<b>Evaporation:</b> None at 65°C	
Peak Pressure	113		
Impulse	113		
Energy	--		
<b>Air, Confined:</b>		<b>Preparation:</b>	
Impulse		The ternary explosive system consisting of RDX, PETN and TNT is prepared by adding the appropriate weight of water-wet RDX to a pentolite (30/70) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-2 is also prepared by adding water-wet PETN to RDX Composition B.	
<b>Under Water:</b>			
Peak Pressure		<b>Compatibility with Metals:</b>	
Impulse		Dry: Aluminum, mild steel not affected.	
Energy			
<b>Underground:</b>		Wet: Aluminum not affected.	
Peak Pressure			
Impulse			
Energy			
<b>Booster Sensitivity Test:</b>			
(c)			
Condition	Pressed	Cast	
Tetryl, gm	100	100	
Wax, in. for 50% Detonation	1.87	2.32	
Density, gm/cc	1.70	1.61	

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor-piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/PETN/TNT, designated PTX-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered promise but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References:<sup>66</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 13 June 1949.
- (d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

0	2	3	4	5	6	8	9
1530	1482	1483 1623	1414	1445	1466	1838	1379 1429 1460

<sup>66</sup>See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b>	217
RDX	90	Oxygen Balance: CO <sub>2</sub> %	-37
Polyvinyl Acetate	8	CO %	-10
Dibutylphthalate	2	<b>Density:</b> gm/cc <b>Pressed</b>	1.60
<b>C/H Ratio</b>		<b>Melting Point:</b> °C <b>Softening Point:</b> °C	99
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	39	<b>Freezing Point:</b> °C	
Sample Wt 20 mg		<b>Boiling Point:</b> °C	
Picatinny Arsenal Apparatus, in.	9	<b>Refractive Index:</b> n <sub>D<sup>20</sup></sub>	
Sample Wt, mg	13	n <sub>D<sup>25</sup></sub>	
		n <sub>D<sup>40</sup></sub>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Steel Shoe	Crackles	90°C	
Fiber Shoe	Unaffected	100°C	0.45
		120°C	0.88
<b>Rifle Bullet Impact Test: 5 Trials *</b>	%	135°C	--
Explosions	20	150°C	11+
Partials	0	<b>200 Gram Bomb Sand Test:</b>	
Burned	60	Sand, gm	58.5
Unaffected	20		
*100 trials at -46°C - Unaffected			
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	--	Minimum Detonating Charge, gm	
1	330	Mercury Fulminate	
5 Decomposes	375	Lead Azide	0.22
10	265	Tetryl	
15		<b>Ballistic Mortar, % TNT:</b>	
20		<b>Trend Test, % TNT:</b>	
<b>75°C International Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss in 48 Hrs		Method	
<b>100°C Heat Test:</b>		Condition	
% Loss, 1st 48 Hrs	0.10	Confined	
% Loss, 2nd 48 Hrs	0.06	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
<b>Flammability Index:</b>		<b>Detonation Rate:</b>	
<b>Hygroscopicity:</b> %	30°C, 90% RH	Confinement	None
	0.20	Condition	Cast†
<b>Velocity:</b>	55°C, vacuo, 6 hrs	Charge Diameter, in.	1.0
	0.03	Density, gm/cc	1.60
		Rate, meters/second	7910

<b>Polymerization Test:</b>	
90 mm HE, M71 Projectile, Lot WC-91:	
Density, gm/cc	
Charge Wt, lb	
<b>Total No. of Fragments:</b>	
For TNT	
For Subject HE	
3 inch HE, M43A1 Projectile, Lot KC-8:	
Density, gm/cc	
Charge Wt, lb	
<b>Total No. of Fragments:</b>	
For TNT	
For Subject HE	
<b>Fragments Velocity: ft/sec</b>	
At 9 ft	
At 25½ ft	
Density, gm/cc	
<b>Blast (Relative to TNT):</b>	
Air:	
Peak Pressure	
Impulse	
Energy	
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	
<b>Shaped Charge Effectiveness, TNT = 100:</b>	
Glass Cones      Steel Cones	
Hole Volume	
Hole Depth	
Color:	White
Principal Uses:	Demolition charges
Method of Loading:	Pressed or extruded
Loading Density: gm/cc	1.60
Storage:	
Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None at 71°C
<b>Plasticity:</b>	
-40°C	Cracked
25°C	0.3

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**PVA-4**

**Preparation:**

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DEP). This formulation was developed by Mr. Sutherland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial name or designation "AYAT" was the most promising coating for RDX in the proportions RDX/PVA(AYAT)/DEP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDX slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acetone solution of PVA + DEP to a hot water slurry of RDX, under agitation, was adopted as standard.

**References:** 67

- (a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

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<sup>67</sup>See footnote 1, page 10.

PVN (Polyvinyl Nitrate)

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<p><b>Composition:</b> %</p> <p>C 27</p> <p>H 3.4</p> <p>N 15.6</p> <p>O 54</p> <p>C/H Ratio 0.203</p> <p><b>Impact Sensitivity, 2 Kg Wt:</b> 14.86 ft Bureau of Mines Apparatus, cm -- Sample Wt 20 mg</p> <p><b>Picatinny Arsenal Apparatus, In.</b> 4 Sample Wt, mg</p> <p><b>Friction Pendulum Test:</b> Steel Shoe Crackles Fiber Shoe Unaffected</p> <p><b>BBM Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected</p> <p><b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 265 10 15 20</p> <p><b>75°C International Heat Test:</b> % Loss in 48 Hrs</p> <p><b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 1.9 % Loss, 2nd 48 Hrs 2.1 Explosion in 100 Hrs None</p> <p><b>Flammability Index:</b></p> <p><b>Hygrosensitivity:</b> % 30°C, 90% RH 0.62</p> <p><b>Volatility:</b></p>	<p><b>Molecular Weight:</b> <math>(C_2H_3NO_3)_n</math> (89)<sub>n</sub></p> <p><b>Oxygen Balance:</b> C, % -45 CO % -9</p> <p><b>Density:</b> gm/cc</p> <p><b>Melting Point:</b> °C (Soft Pb) 50</p> <p><b>Frosting Point:</b> °C</p> <p><b>Boiling Point:</b> °C</p> <p><b>Refractive Index:</b> <math>n_{D}^2</math> <math>n_{D}^2</math> <math>n_{D}^2</math></p> <p><b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 16 hours 11+ 120°C 16 hours 11+ 135°C 150°C</p> <p><b>200 Gram Bomb Sand Test:</b> Sand, gm 49.9</p> <p><b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide Tetryl</p> <p><b>Ballistic Mortar, % TNT:</b></p> <p><b>Trend Test, % TNT:</b></p> <p><b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Briance, % TNT</p> <p><b>Detonation Rate:</b> Confinement Condition Chrgs Diameter, in. Density, gm/cc Rate, meters/second</p>

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PVN (Polyvinyl Nitrate)

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cover</th> <th>Steel Cover</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <b>Coden:</b>  <b>Principal Uses:</b>  <b>Method of Loading:</b>  <b>Loading Density: gm/cc</b>  <b>Storage:</b> <b>Method:</b> <b>Hazard Class (Quantity-Distance)</b> <b>Compatibility Group</b> <b>Eaudation</b>	Glass Cover	Steel Cover	Hole Volume		Hole Depth																			
Glass Cover	Steel Cover																									
Hole Volume																										
Hole Depth																										
<b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy		<u>65.5°C KI Test:</u> <table> <thead> <tr> <th>Minutes</th> <th>Minutes</th> </tr> </thead> <tbody> <tr> <td>60+</td> <td></td> </tr> </tbody> </table> <u>134.5°C Heat Test:</u> <table> <thead> <tr> <th>Salmon Pink</th> <th>Minutes</th> </tr> </thead> <tbody> <tr> <td>Red Fumes</td> <td>20</td> </tr> <tr> <td>Explodes</td> <td>25</td> </tr> <tr> <td></td> <td>300+</td> </tr> </tbody> </table> <u>240-Hour Hydrolysis Test:</u> <table> <thead> <tr> <th><math>\frac{1}{2}</math> HNO<sub>3</sub></th> <th>Minutes</th> </tr> </thead> <tbody> <tr> <td></td> <td>5.07</td> </tr> </tbody> </table> <u>Heat of:</u> <table> <thead> <tr> <th>Combustion, cal/gm</th> <th>Minutes</th> </tr> </thead> <tbody> <tr> <td>2960</td> <td></td> </tr> <tr> <td>Explosion, cal/gm</td> <td>900</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>836</td> </tr> </tbody> </table>	Minutes	Minutes	60+		Salmon Pink	Minutes	Red Fumes	20	Explodes	25		300+	$\frac{1}{2}$ HNO <sub>3</sub>	Minutes		5.07	Combustion, cal/gm	Minutes	2960		Explosion, cal/gm	900	Gas Volume, cc/gm	836
Minutes	Minutes																									
60+																										
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	5.07																									
Combustion, cal/gm	Minutes																									
2960																										
Explosion, cal/gm	900																									
Gas Volume, cc/gm	836																									

PVN (Polyvinyl Nitrate)

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Preparation:

Polyvinyl alcohol is mixed with acetic anhydride. The mixture is cooled to -5°C and the nitric acid is added slowly while the mass is being stirred. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above 20°C.

When the nitration is complete, the mixture is drowned by allowing a fine stream of the syrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50°C. (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

<b>Composition:</b> %		<b>Molecular Weight:</b>	230
RDX	85	Oxygen Balance: CO <sub>2</sub> %	.70
Gulf Crown E Oil	15	CO %	.35
C/H Ratio		Density: gm/cc Hand tamped	1.37
Spost Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	53	Melting Point: °C	
Sample Wt 20 mg		Freezing Point: °C	
Picatinny Arsenal Apparatus, in.	13	Boiling Point: °C	
Sample Wt, mg	25	Refractive Index, n <sub>D</sub> <sub>20</sub>	n <sub>D</sub> <sub>20</sub> n <sub>D</sub> <sub>25</sub> n <sub>D</sub> <sub>30</sub>
Fallion Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	--
Life Bullet Impact Test: Trials	%	100°C	0.34
Explosions	0	120°C	0.56
Partials	0	135°C	
Burned	0	150°C	
Unaffected	100	200 Gram Bomb Sand Test:	
Explosion Temperature: °C Seconds, 0.1 (no cap used)		Sand, gm	40.1
1		Sensitivity to Initiation:	
5 Decomposes; no value obtained		Minimum Detonating Charge, gm	
10		Mercury Fulminate	
15		Lead Azide	0.20
20		Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Meter, % TNT: (a)	118
100°C Heat Test: % Loss, 1st 48 Hrs	0.03	Trossz Test, % TNT:	
% Loss, 2nd 48 Hrs	.04	Plate Dent Test: (b)	
Explosion in 100 Hrs	None	Method	B
Flammability Index:		Condition	Hand tamped
Hygroscopicity: % 30°C, 50% RH	0.04	Confined	No
Volatility:		Density, gm/cc	1.37
		Briance, % TNT	85
		Detonation Rate:	
		Confinement	None
		Condition	Hand tamped
		Charge Diameter, in.	1.0
		Density, gm/cc	1.37
		Rate, meters/second	7390

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness: TNT = 100:</b>			
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones		
Density, gm/cc	1.36	Hole Volume			
Charge Wt, lb	1.766	Hole Depth			
<b>Total No. of Fragments:</b>		<b>Color:</b>			
For TNT	703	White			
For Subject HE	592				
3 inch HE, M42A1 Projectile, Lot KC-31:		<b>Principal Uses:</b> Plastic demolition explosive			
Density, gm/cc	1.42				
Charge Wt, lb	0.756				
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>			
For TNT	514	Hand tamped			
For Subject HE	501				
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>			
At 9 ft	2650	1.37			
At 25½ ft	2370				
Density, gm/cc	1.395	<b>Storage:</b>			
<b>Blast (Relative to TNT):</b>		<b>Method</b>			
Air:		Dry			
Peak Pressure					
Impulse					
Energy					
Air, Confined:		<b>Hazard Class (Quantity-Distance)</b>			
Impulse		Class 9			
Under Water:		<b>Compatibility Group</b>			
Peak Pressure		Group I			
Impulse		None at 85°C in 30 hrs			
Energy		None at 95°C in 48 hrs			
Underground:		Exudation None at 105°C in 48 hrs			
Peak Pressure					
Impulse					
Energy					
<b>Preparation:</b>		<b>Origin:</b>			
RIPE is manufactured by simple mechanical mixing of RDX in oil.		RIPE, a mechanical mixture of RDX and Gulf Crown E Oil, was developed in the United States during World War II.			
<b>References:</b>					
(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests</u> , OSRD Report No. 746, 27 December 1945.					
(b) D. P. MacDougall, <u>Methods of Physical Testing</u> , OSRD Report No. 803, 11 August 1942.					
(c) Also see the following Picatinny Arsenal Technical Reports on RIPE: 1713, 1695 and 1517.					

68See footnote 1, page 10.

Silver Azide

<b>Composition:</b> %	<b>Molecular Weight:</b> (AgN <sub>3</sub> ) 150	
N 28.0		
Ag 72.0		
Ag-N=N≡N		
<b>C/H Ratio</b>		
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 6	<b>Oxygen Balance:</b> CO <sub>2</sub> % -5 CO % -5	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in. 3		
Sample Wt, mg 18		
<b>Friction Pendulum Test: PA Small Apparatus</b>	<b>Density:</b> gm/cc <b>Crystal</b> 5.1	
Steel Shoe Detonates		
Fiber Shoe Detonates		
<b>Rifle Bullet Impact Test:</b> Trials	<b>Melting Point:</b> °C (a) 251 Decomposes rapidly above melting point to silver and nitrogen.	
Explosions %		
Partials		
Burned		
Unaffected		
<b>Exploding Temperature:</b> °C	<b>Freezing Point:</b> °C	
Seconds, 0.1 (no cap used) 310		
1		
5 Explodes --		
10		
15		
20		
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Boiling Point:</b> °C	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	
% Loss, 2nd 48 Hrs	n <sub>D</sub> <sup>20</sup>	
Explosion in 100 Hrs	n <sub>D</sub> <sup>20</sup>	
<b>Flammability Index:</b>	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
<b>Hygroscopicity:</b> % (b) 25°C, 100% RH 0.04	90°C	
<b>Volatility:</b> 75°C, 24 hrs 0.00	100°C	
	120°C	
	135°C	
	150°C	
	<b>200 Gram Bomb Shock Test:</b> Shock, gm (b)	
	Black powder fuse 18.9	
	<b>Sensitivity to Initiation:</b>	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	
	Lead Azide	
	Tetryl	
	<b>Ballistic Meter, % TNT:</b>	
	<b>Trend Test, % Hg(O NC)<sub>2</sub> (c)</b> 88	
	<b>Plate Dent Test:</b>	
	Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
	<b>Detonation Rate:</b>	
	Confinement	
	Condition	
	Charge Diameter, in.	
	Density, gm/cc	
	Rate, meters/second	

Silver Azide

AMCP 706-177

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Color:</th> <th>White to gray</th> </tr> </thead> <tbody> <tr> <td>Principal Uses:</td> <td>Initiators</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Method of Loading:</th> <th>Pressure</th> </tr> </thead> <tbody> <tr> <td>Loading Density: gm/cc</td> <td>Variable</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Storage:</th> <th></th> </tr> </thead> <tbody> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">Initiating Efficiency:</th></tr> </thead> <tbody> <tr> <td>Grams Required to Give Complete Initiation of TNT</td><td>(c) 0.02-0.05</td></tr> <tr> <th colspan="2"><u>Solubility in 100 gm Solvent at Room Temperature:</u></th></tr> <tr> <th>Solvent</th><th>Grams</th></tr> <tr> <td>Water (b)</td><td>0.006</td></tr> <tr> <td>Ammonium hydroxide</td><td>Soluble</td></tr> <tr> <td>Nitric acid</td><td>Decomposes</td></tr> <tr> <td>Ether (b)</td><td>0.017</td></tr> <tr> <td>Ethyl alcohol, 95%</td><td>0.006</td></tr> <tr> <td>Acetone</td><td>0.015</td></tr> <tr> <td>Unaffected by water and CO<sub>2</sub>.</td><td>(d)</td></tr> <tr> <th>Heat of:</th><th></th></tr> <tr> <td>Explosion, cal/gm (c, a)</td><td>452</td></tr> <tr> <td>Formation, cal/gm (e)</td><td>67.8</td></tr> </tbody> </table>		Glass Cones	Steel Cones	Hole Volume		Hole Depth		Color:	White to gray	Principal Uses:	Initiators	Method of Loading:	Pressure	Loading Density: gm/cc	Variable	Storage:		Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M	Exudation	None	Initiating Efficiency:		Grams Required to Give Complete Initiation of TNT	(c) 0.02-0.05	<u>Solubility in 100 gm Solvent at Room Temperature:</u>		Solvent	Grams	Water (b)	0.006	Ammonium hydroxide	Soluble	Nitric acid	Decomposes	Ether (b)	0.017	Ethyl alcohol, 95%	0.006	Acetone	0.015	Unaffected by water and CO <sub>2</sub> .	(d)	Heat of:		Explosion, cal/gm (c, a)	452	Formation, cal/gm (e)	67.8
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<b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy  <b>Explosive Power: (f)</b>  Kilogram meters % Mercury Fulminate		192,000 1.097																																																					

Preparation:

Prepare the following aqueous solutions:

- a. 5%  $\text{NaN}_3$ , sodium azide, 50 cc
- b. 25%  $\text{AgNO}_3$ , silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium azide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is fastened to the stopcock of the separatory funnel so that the funnel can be emptied by remote control. The silver nitrate solution is now stirred very rapidly and the sodium azide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and washed free of sodium azide and silver nitrate with distilled water.

Silver azide should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver azide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver azide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver azide (Ref g). White silver azide is less affected by light than mercury or lead azide (Ref h). Long colorless crystals which explode on breaking are obtained from ammonium hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazic acid ( $\text{HN}_3$ ) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "colloidal" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925)). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref i).

References:<sup>69</sup>

- (a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).
- (b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).
- (c) E. De W. S. Colver, High Explosives, London and New York, p. 527.
- (d) A. Stettbacher, Spreng u. Schießstoffe, Rascher, Zurich, p. 97 (1948).
- (e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.
- (f) A. Stettbacher, Z ges Schieß-Sprengstoffw 10, pp. 193-214 (1915).

<sup>69</sup>See footnote 1, page 10.

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- (g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 26, 646.
- (h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).
- (i) F. G. Heverlak, Examination of 120/15 MM HE Shell, Italian (FMAM-464), PATR No. 1515, 10 April 1945.

Tetracene

<b>Composition:</b> %	<b>Molecular Weight:</b> ( $C_{28}H_{10}O$ ) 188
C 12.8 H 4.3 N 74.4 O 8.5	Oxygen Balance: CO <sub>2</sub> % -60 CO % -43
	<b>Density:</b> gm/cc At 3000 psi 1.05
C/H Ratio 0.068	<b>Melting Point:</b> °C Explodes 140-160
	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 7 Sample Wt 20 mg	<b>Boiling Point:</b> °C
Picatinny Arsenal Apparatus, in.2; (8 oz wt) 8 Sample Wt, mg	<b>Refractive Index:</b> n <sub>D<sup>20</sup></sub> n <sub>D<sup>25</sup></sub> n <sub>D<sup>30</sup></sub>
<b>Fritiles Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Send Test:</b> Send, gm 28.0 BLACK powder fuse 4.0
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 160 10 15 20	<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate 0.40 Lead Azide Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.5	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 23.2 % Loss, 2nd 48 Hrs 3.4 Explosion in 100 Hrs None	<b>Trenzi Test, % TNT:</b> (a) 61
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.77	Brisance, % TNT
<b>Volatility:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second

Tetracene

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb		Glass Cones	Steel Cones
<b>Total No. of Fragments:</b> For TNT For Subject HE		Hole Volume	Hole Depth
<b>3 inch HE, M42A1 Projectile, Lot KC-8:</b> Density, gm/cc Charge Wt, lb		<b>Color:</b> Pale yellow	
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Principal Uses:</b> Priming compositions and detonators	
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc		<b>Method of Loading:</b> Pressed	
<b>Blast (Relative to TNT):</b>		<b>Loading Density: gm/cc</b> At 3000 psi 1.05	
<b>Air:</b> Peak Pressure Impulse Energy		<b>Storage:</b>	
<b>Air, Confined:</b> Impulse		Method	Wet
<b>Under Water:</b> Peak Pressure Impulse Energy		Hazard Class (Quantity-Distance)	Class 9
<b>Underground:</b> Peak Pressure Impulse Energy		Compatibility Group	Group M
<b>Solubility:</b>		Exudation	
		Practically insoluble in water, alcohol, acetone, ether, benzene, carbontetrachloride or ethylenedichloride.	
		<b>Sensitivity to Electrostatic Discharge, Joules:</b> (b)	
		Unconfined	0.010
		Confined	0.012
		<b>Heat of:</b>	
		Explosion, cal/gm	658
		Gas Volume, cc/gm	1190
<b>Initiating Efficiency:</b>		Tetracene is not efficient in initiating high explosives.	

TetracenePreparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0°C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10°C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water heated to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber 43, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber 43, 1087, 1866 (1910); Ber 44, 2496 (1911); and Ann 30, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance 12, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References: <sup>70</sup>

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives. Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

<u>0</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1450	11	453	1104 2164	407	318	859 2179

<sup>70</sup>See footnote 1, page 10.

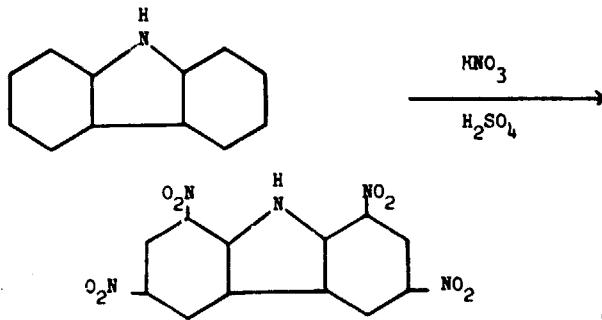
Tetranitrocarbazole (TNC)

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<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>12</sub> H <sub>5</sub> N <sub>5</sub> O <sub>8</sub> ) 347
C 41.6	Oxygen Balance: CO <sub>2</sub> % -85
H 1.4	CO % -30
N 20.0	<b>Density:</b> gm/cc
O 37.0	<b>Melting Point:</b> °C Pure 1,3,6,8-isomer 296
C/H Ratio 1.032	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg	<b>Boiling Point:</b> °C
Platinnay Arsenal Apparatus, in. 18 Sample Wt, mg 14	<b>Refractive Index:</b> n <sub>D<sup>20</sup></sub> n <sub>D<sup>25</sup></sub> n <sub>D<sup>30</sup></sub>
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.2 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 41.3
<b>Explosion Temperature:</b> °C Second: 0.1 (no cap used) -- -- 5 D <sub>4</sub> decomposes 470 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.25
<b>75°C Intermediate Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	<b>Treuzzi Test, % TNT:</b>
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.01	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Volatility:</b>	

Tetranitrocarbazole (TNC)

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-8: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <b>Color:</b> Light yellow	Glass Cones	Steel Cones	Hole Volume		Hole Depth											
Glass Cones	Steel Cones																	
Hole Volume																		
Hole Depth																		
		<b>Principal Uses:</b> Component of igniter and pyrotechnic compositions																
		<b>Method of Loading:</b> Pressed																
		<b>Loading Density:</b> gm/cc																
		<b>Storage:</b> <table> <tr> <td><b>Method</b></td> <td>Dry</td> </tr> <tr> <td><b>Hazard Class (Quantity-Distance)</b></td> <td>Class 9</td> </tr> <tr> <td><b>Compatibility Group</b></td> <td></td> </tr> <tr> <td><b>Exudation</b></td> <td></td> </tr> </table>	<b>Method</b>	Dry	<b>Hazard Class (Quantity-Distance)</b>	Class 9	<b>Compatibility Group</b>		<b>Exudation</b>									
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<b>Hazard Class (Quantity-Distance)</b>	Class 9																	
<b>Compatibility Group</b>																		
<b>Exudation</b>																		
<b>Blow (Relative to TNT):</b> Air: Peak Pressure Impulse Energy  Air, Confined: Impulse		<b>Solubility in Water,</b> <u>gm/100 gm (%) at:</u> 95°C                            0.10																
Under Water: Peak Pressure Impulse Energy		<u>Qualitative Solubilities:</u> <table> <thead> <tr> <th><u>Solvent</u></th> <th><u>Solubility</u></th> </tr> </thead> <tbody> <tr> <td>Nitrobenzene</td> <td>Very soluble</td> </tr> <tr> <td>Acetone</td> <td>Soluble</td> </tr> <tr> <td>Benzene</td> <td>Insoluble</td> </tr> <tr> <td>Chloroform</td> <td>Insoluble</td> </tr> <tr> <td>Carbontetrachloride</td> <td>Insoluble</td> </tr> <tr> <td>Ether</td> <td>Insoluble</td> </tr> <tr> <td>Ether, petroleum</td> <td>Insoluble</td> </tr> </tbody> </table>	<u>Solvent</u>	<u>Solubility</u>	Nitrobenzene	Very soluble	Acetone	Soluble	Benzene	Insoluble	Chloroform	Insoluble	Carbontetrachloride	Insoluble	Ether	Insoluble	Ether, petroleum	Insoluble
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Carbontetrachloride	Insoluble																	
Ether	Insoluble																	
Ether, petroleum	Insoluble																	
Underground: Peak Pressure Impulse Energy																		

Tetranitrocarbazole (TNC)Preparation:

Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of  $\text{H}_2\text{SO}_4$  (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at 25°-35°C. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to 80°-85°C and maintaining this temperature for one hour. The sulphate is now cooled to 20°C.

Nitration: The sulfonate solution is slowly added to 168 gms of  $\text{HNO}_3$  (Plant grade specific gravity 1.525 at 15°C) maintaining the temperature at 30° to 50°C. (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and water.

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

Purification: The TNC is placed in hot water (95° to 100°C) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 (1909)). However, G. L. Ciamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim Ital 12, 272 (1882)). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,536). The Casella process of

Tetranitrocarbazole (TNC)

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc 75, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References: <sup>71</sup>

- (a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbazole," J Am Chem Soc, 75, 4289-4291 (1953).
- (b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136,330, 11 April 1951.
- (c) D. B. Murphy et al, Long Range Basic Technical Research Leading to the Development of Improved Ignition Type Powders - The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.
- (d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>I</u>
2180	1802	1973	1984	1647 1937

<sup>71</sup>See footnote 1, page 1C.

2,4,2',4'-Tetranitro-oxanilide (TNO)

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<b>Composition:</b> %	<b>Molecular Weight:</b> (C <sub>14</sub> H <sub>8</sub> N <sub>6</sub> O <sub>10</sub> )	420
C 40.0	CO <sub>2</sub> %	-84
H 1.9	CO %	-31
N 20.0	<b>Density:</b> gm/cc	
O 38.1	<b>Melting Point:</b> °C	Decomposes
C/H Ratio 0.735		313
	<b>Freezing Point:</b> °C	
	<b>Boiling Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	n <sub>D</sub> <sup>20</sup>	
	n <sub>D</sub> <sup>25</sup>	
	n <sub>D</sub> <sup>30</sup>	
<b>Friction Pendulum Test:</b> Steel Shoe                          Unaffected	<b>Vacuum Stability Test:</b>	
Fiber Shoe                          Unaffected	cc/40 Hrs, at	
	90°C	--
	100°C	--
	120°C	0.11
	135°C	
	150°C	
<b>Rifle Bullet Impact Test:</b> Trials Explosions                          %	<b>200 Gram Bomb Sand Test:</b>	
Partials	Sand, gm	16.3
Burned		
Unaffected		
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)     --	<b>Sensitivity to Initiation:</b>	
1                                  --	Minimum Detonating Charge, gm	
5                                  392	Mercury Fulminate	
10	Lead Azide	0.20
15	Tetryl	0.25
20		
<b>75°C Intersitial Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs                0.07	<b>Treuzl Test, % TNT:</b>	
% Loss, 2nd 48 Hrs                0.00	<b>Plate Dent Test:</b>	
Explosion in 100 Hrs            None	Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
<b>Flammability Index:</b>	<b>Detonation Rate:</b>	
<b>Hygroscopicity:</b> % 30°C, 90% RH      Trace	Confinement	
<b>Volatility:</b>	Condition	
	Charge Diameter, in.	
	Density, gm/cc	
	Rate, meters/second	

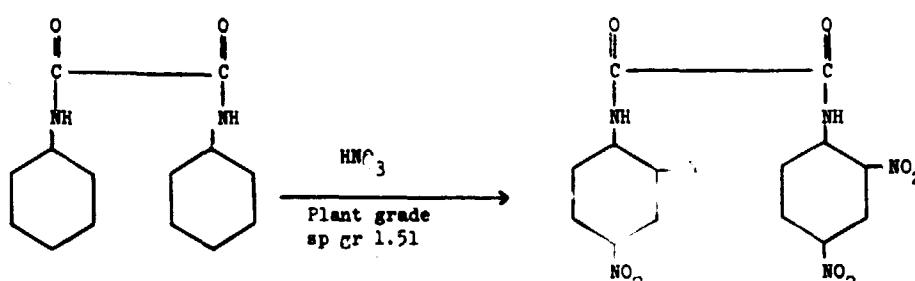
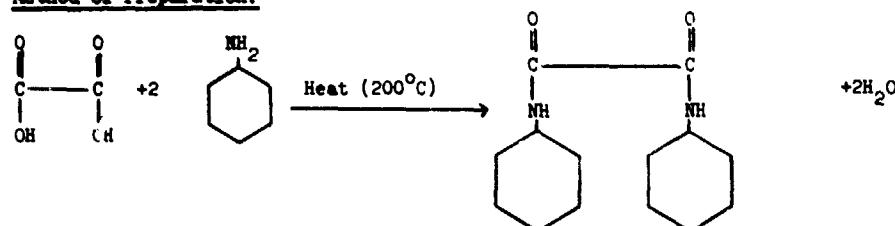
2,4,2',4'-Tetranitro-oxanilide (TNO)

<p><b>Fragmentation Test:</b></p> <p>90 mm HE, M71 Projectile, Lot WC-91:</p> <p>Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT For Subject HE</p> <p>3 inch HE, M42A1 Projectile, Lot KC-5:</p> <p>Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> Light yellow</p> <p><b>Principal Uses:</b> Component of black powder type and pyrotechnic compositions</p>	Glass Cones	Steel Cones	Hole Volume		Hole Depth																								
Glass Cones	Steel Cones																													
Hole Volume																														
Hole Depth																														
<p><b>Fragment Velocity:</b> ft/sec</p> <p>At 9 ft At 25½ ft</p> <p>Density, gm/cc</p>	<p><b>Method of Loading:</b> Pressed and extruded compositions</p>																													
<p><b>Blast (Relative to TNT):</b></p> <p>Air:</p> <p>Peak Pressure Impulse Energy</p> <p>Air, Confined:</p> <p>Impulse</p>	<p><b>Leading Density:</b> gm/cc</p> <p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group</p> <p>Exudation</p>																													
<p>Under Water:</p> <p>Peak Pressure Impulse Energy</p> <p>Underground:</p> <p>Peak Pressure Impulse Energy</p>	<p><b>Solubility, gm/100 cc Solvent, in:</b></p> <table border="1"> <thead> <tr> <th></th> <th style="text-align: center;"><math>^{\circ}\text{C}</math></th> <th style="text-align: center;">%</th> </tr> </thead> <tbody> <tr> <td>Water</td> <td style="text-align: center;">100</td> <td style="text-align: center;"><math>&lt;0.10</math></td> </tr> <tr> <td>Nitrobenzene</td> <td style="text-align: center;">150</td> <td style="text-align: center;"><math>&gt;15</math></td> </tr> </tbody> </table> <p><b>Qualitative Solubilities:</b></p> <table border="1"> <thead> <tr> <th>Solvent</th> <th>Solubility</th> </tr> </thead> <tbody> <tr> <td>Ethyl alcohol</td> <td>Insoluble</td> </tr> <tr> <td>Benzene</td> <td>Insoluble</td> </tr> <tr> <td>Butyl acetate</td> <td>Insoluble</td> </tr> <tr> <td>Carbontetrachloride</td> <td>Insoluble</td> </tr> <tr> <td>Ethyl ether</td> <td>Insoluble</td> </tr> <tr> <td>Acetic acid</td> <td>Soluble</td> </tr> <tr> <td>Nitric acid</td> <td>Soluble</td> </tr> <tr> <td>Caustic potash</td> <td>Soluble</td> </tr> <tr> <td>Dimethyl formamide</td> <td>Very soluble</td> </tr> </tbody> </table>		$^{\circ}\text{C}$	%	Water	100	$<0.10$	Nitrobenzene	150	$>15$	Solvent	Solubility	Ethyl alcohol	Insoluble	Benzene	Insoluble	Butyl acetate	Insoluble	Carbontetrachloride	Insoluble	Ethyl ether	Insoluble	Acetic acid	Soluble	Nitric acid	Soluble	Caustic potash	Soluble	Dimethyl formamide	Very soluble
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#### 2,4,2',4'-Tetranitro-oxanilide (TNO)

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#### **Method of Preparation:**



### **Organilide:**

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water (21°-24°C), filtered on a Bichner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at 100°-110°C.

#### Tetranitro-oxanilide (TNO):

A 5 liter round bottom flask is equipped with a stirrer of a type which will produce a downward "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of oxanilide is slowly added to the acid under rapid agitation while the temperature is maintained below 40°C. After the addition of the oxanilide is completed (2½-3 hrs.), the agitation is continued 10-15 minutes. The temperature is then raised to 80°C over a period of one hour and maintained at 80°-85°C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ice. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

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2,4,2',4'-Tetranitro-oxanilide (TNO)

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100°-110°C.

Yield = 90% to 97.5% of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892)).

References:<sup>72</sup>

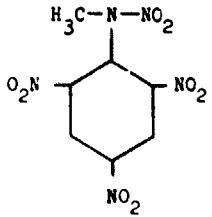
(a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

(b) D. Dubrow and J. Kristel, Substitution of Tetranitro OXANILIDE and Hexanitro OXANILIDE for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-88, 20 December 1954.

<sup>72</sup>See footnote 1, page 10.

Tetryl

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<b>Composition:</b> % C 29.3 H 1.7 N 24.4 O 44.6 C/H Ratio 0.420		<b>Molecular Weight:</b> (C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>8</sub> ) 287
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 26 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 8 Sample Wt, mg 18		<b>Oxygen Balance:</b> CO <sub>2</sub> % -47 CO % -8
<b>Friction Pendulum Test:</b> Steel Shoe Crackles Fiber Shoe Unaffected		<b>Density:</b> gm/cc Crystal 1.73
<b>Rifle Bullet Impact Test:</b> Trials % Explosions 13 Partials 54 Burned 10 Unaffected 23		<b>Melting Point:</b> °C 130
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 340 1 314 5 Ignites 257 10 238 15 236 20 234		<b>Freezing Point:</b> °C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.01		<b>Boiling Point:</b> °C
<b>100°C Heat Test:</b> % loss, 1st 48 Hrs 0.1 % loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		<b>Refractive Index:</b> n <sub>D</sub> n <sub>D</sub> n <sub>D</sub>
<b>Flammability Index:</b> 244		<b>Vacuum Stability Test:</b> cc/40 Hrs. at 90°C -- 100°C 0.3 120°C 1.0 135°C -- 150°C 11+
<b>Hygroscopicity:</b> % 27°C, 90% RH 0.04		<b>200 Gram Bomb Sand Test:</b> Sand, gm 54.2
<b>Volatility:</b> 25°C 0.00		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.20* Lead Azide 0.10* <b>*Alternative initiating charges.</b>
		<b>Ballistic Mortar, % TNT:</b> (a) 130
		<b>Trevizi Test, % TNT:</b> (b) 125
		<b>Plate Dent Test:</b> (c) Method A B Condition Pressed Pressed Confined Yes No Density, gm/cc 1.50 1.59 1.36 Brisance, % TNT 116 115 96
		<b>Detonation Rate:</b> Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.71 Rate, meters/second 7850

<b>Booster Sensitivity Test:</b>	(d)	<b>Decomposition Equation:</b>	(g)	(h)
Condition	Pressed	Oxygen, atoms/sec (Z/sec)	$10^{15.4}$	$10^{12.9}$
Tetryl, gm	100	Heat, kilocalorie/mole ( $\Delta H$ , kcal/mol)	38.4	34.9
Wax, in. for 50% Detonation	2.01	Temperature Range, °C	211-260	132-164
Wax, gm		Phase	Liquid	Liquid
Density, gm/cc	1.58			
<b>Heat of:</b>				
Combustion, cal/gm	2925			
Explosion, cal/gm	1080-1130			
Gas Volume, cc/gm	760			
Formation, cal/gm	-14			
Fusion, cal/gm, °C	(e) 22.2			
Temperature, °C	127			
<b>Specific Heat: cal/gm/°C</b>	(e)			
-100	0.182			
-50	0.200			
0	0.212			
50	0.223			
100	0.236			
<b>Burning Rate:</b>				
cm/sec				
<b>Thermal Conductivity:</b> (f)				
cal/sec/cm/°C $5.81 \times 10^{-4}$ at 1.394 gm/cc				
$6.83 \times 10^{-4}$ at 1.528 gm/cc				
<b>Coefficient of Expansion:</b>				
Linear, %/°C				
Volume, %/°C				
<b>Hardness, Mohs' Scale:</b>				
<b>Young's Modulus:</b>				
E', dynes/cm <sup>2</sup>				
E, lb/inch <sup>2</sup>				
Density, gm./cc				
<b>Compressive Strength: lb/inch<sup>2</sup></b>				
Vapor Pressure:				
°C mm Mercury				

Tetryl

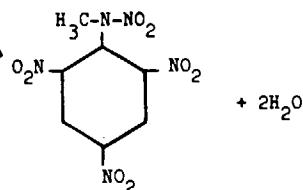
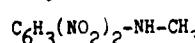
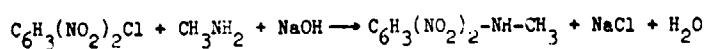
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Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:						
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones					
Density, gm/cc	1.58	Hole Volume						
Charge Wt, lb	2.052	Hole Depth						
Total No. of Fragments:		Color:						
For TNT	703	Light yellow						
For Subject HE	864							
3 inch HE, M42A1 Projectile, Lot KC-5:		Principal Uses:						
Density, gm/cc	1.62	Boosters; ingredient of explosive mixtures, detonators, and blasting caps						
Charge Wt, lb	0.848							
Total No. of Fragments:		Method of Loading:						
For TNT	514	Pressed						
For Subject HE	605							
Fragment Velocity: ft/sec		Loading Density: gm/cc						
At 9 ft		See below						
At 25½ ft								
Density, gm/cc		Storage:						
Blow (Relative to TNT):		Method	Dry					
Air:		Hazard Class (Quantity-Distance)						
Peak Pressure		Class 9						
Impulse		Compatibility Group						
Energy		Group L						
Air, Confined:		Exudation	Does not exude at 65°C					
Impulse		Loading Density: gm/cc						
Under Water:		Cast 1.62      Pressed      psi x 10 <sup>3</sup>						
Peak Pressure		0	3	5	10	12	15	20
Impulse		0.9	1.40	1.47	1.57	1.60	1.63	1.67
Energy					30			
Underground:						1.71		
Peak Pressure		Effect of Temperature on (J) Rate of Detonation:						
Impulse								
Energy		16 hrs at, °C	-54	21				
		Density, gm/cc	1.52	1.53				
		Rate, m/sec	7150	7170				

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TetrylPreparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Co., Inc.)



To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C)

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.6/18.2 sulfuric/nitric/water).
2. Nitration maximum temperature is 50°C.
3. The slurry is cooled to 35°C before filtration.
4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurities and occluded acid and to control its granulation.

TetrylSensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (i)

Unconfined	0.007
Confined	4.4

Solubility of tetryl, grams in 100 grams (%) of:

<u>Water</u>		<u>Carbon tetrachloride</u>		<u>Ether</u>		<u>95% Alcohol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.0050	0	0.007	0	0.188	0	0.320
20	0.0075	20	0.015	10	0.330	10	0.425
40	0.0110	40	0.058	20	0.418	20	0.563
60	0.0810	60	0.154	30	0.493	30	0.76
100	0.184					50	1.72
						75	5.33

<u>Chloroform</u>		<u>Carbon disulfide</u>		<u>Ethylene dichloride</u>		<u>Acetone</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.28	0	0.009	25	4.5	20	75
20	0.39	10	0.015	75	45	30	95
40	1.20	20	0.021			40	116
60	2.65	30	0.030			50	138

<u>Trichloroethylene</u>		<u>Ethyl acetate</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.07	20	~40	20	7.8	20	8.5
20	0.12			30	10.0		
40	0.26			40	12.5		
60	0.67			50	16.0		
80	1.50						
86	1.76						

<u>Xylene</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	3.3	80	32
30	4.4	100	149
40	5.4	120	645
50	6.0		

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite ( $\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$ ) in 4 parts water. The sulfite solution may be heated to 80°C to facilitate decomposition of the Tetryl.

References:<sup>3</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph Naoum, Z ges Schiess---Sprengstoffw, pp. 181, 229, 267 (27 June 1932)
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.
- (e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104.
- (f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.
- (g) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).
- (i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
- (k) Also see the following Picatinny Arsenal Technical Reports on Tetryl:

0	1	2	3	4	5	6	7	8	9
30	11	132	453	84	65	266	117	28	129
500	361	582	493	144	195	556	197	438	179
770	381	832	623	294	425	786	637	628	319
810	621	882	833	314	525	986	707	708	609
1180	861	1192	863	694	565	1086	807	788	709
1290	1041	1352	1113	774	625	1126	837	838	849
1350	1131	1372	1373	784	635	1316	857	1418	959
1360	1261	1402	2053	874	845	1376	1047	1768	1029
1400	1331	1452	2163	904	925	1416	1137	1828	1209
1450	1431	1592	2233	1134	1145	1446	1287	1838	1379
1500	1471			116	1285	1466	1337		1429
1510	1611			123	1405	1556	1367		1489
1670	1651			1264	158	1636	1437	1819	
				2024	1885	1956	1737	1969	
				2204	1935		1797		
					2105		1937		
					2125				
					2205				

<sup>3</sup>See footnote 1, page 16.

Tetrytol, 80/20

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<b>Composition:</b> %		<b>Molecular Weight:</b>	274
Tetryl	80	Oxygen Balance: CO <sub>2</sub> %	-52
TNT	20	CO %	-11
		<b>Density:</b> gm/cc <b>Cast:</b>	1.51
		<b>Melting Point:</b> °C	68
		<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	28	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		Refractive Index, n <sub>d20</sub> n <sub>d25</sub> n <sub>d30</sub>	
Picatinny Arsenal Apparatus, in.	9		
Sample Wt, mg	17		
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
		90°C	
Rifle Bullet Impact Test: Trials	%	100°C	3.0
Explosions	0	120°C	11+
Partials	20	135°C	
Burned	0	150°C	
Unaffected	80	<b>200 Gram Bomb Sand Test:</b> Sand, gm	54.0
<b>Explosion Temperature:</b> °C Seconds, 0.1 (inc cap used)		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.22*
5 Ignites	290	Lead Azide	0.17*
10		Tetryl	
15		*Alternative initiating charges.	
20		<b>Ballistic Mortar, % TNT:</b>	
<b>75°C Intermittent Heat Test:</b> % Loss in 48 Hrs		<b>Tread Test, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	0.1	<b>Plate Dent Test:</b> Method	
% Loss, 2nd 48 Hrs	0.5	Condition	
Explosion in 100 Hrs	None	Confined	
<b>Flammability Index:</b> Will not continue to burn		Density, gm/cc	
<b>Hygroscopicity:</b> %	0.02	Brisance, % TNT	
<b>Vaporility:</b>		<b>Detonation Rate:</b>	
		Confinement	
		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	

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Tetrytol, 80/20

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Gloss Cones      Steel Cones Hole Volume Hole Depth  <b>Color:</b> Light yellow to buff  <b>Principal Uses:</b> Bursters, demolition blocks  <b>Method of Loading:</b>  <b>Loading Density:</b> gm/cc  <b>Storage:</b> Method              Dry Hazard Class (Quantity-Distance)      Class 9 Compatibility Group      Group I Exudation              Exudes at 65°C
--	---

<b>Composition:</b>		<b>Molecular Weight:</b>	270
%			
Tetryl	75	Oxygen Balance:	
TNT	25	CO <sub>2</sub> %	-54
		CO %	-12
<b>C/H Ratio</b>		<b>Density:</b> gm/cc	Cast 1.59
		<b>Melting Point:</b> °C	68
		<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point:</b> °C	
Bureau of Mines Apparatus, cm	28		
Sample Wt 20 mg		<b>Refractive Index, n<sub>d</sub><sup>20</sup>:</b>	
Picatinny Arsenal Apparatus, in.	10	n <sub>d</sub> <sup>20</sup>	
Sample Wt, mg	17	n <sub>d</sub> <sup>25</sup>	
		n <sub>d</sub> <sup>30</sup>	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Cracks	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	3.0
<b>Rifle Bullet Impact Test:</b>	Trials	120°C	11+
Explosions	%	135°C	
Partials	0	150°C	
Buried	30		
Unaffected	70	<b>200 Gram Bomb Sand Test:</b>	
		Sand, gm	53.7
<b>Ex-losion Temperature:</b>	°C	<b>Sensitivity to Initiation:</b>	
1 seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.23*
5 Ignites	310	Lead Azide	0.19*
10		Tetryl	
15		*Alternative initiating charges.	
20		<b>Ballistic Mortar, % TNT:</b>	(a) 122
<b>75°C International Heat Test:</b>		<b>Tren-ti Test, % TNT:</b>	
% Loss in 48 Hrs		<b>Plate Dent Test:</b>	(b)
<b>100°C Heat Test:</b>		Method	B B
% Loss, 1st 48 Hrs		Condition	Cast Cast
% Loss, 2nd 48 Hrs		Confined	No Yes
Explosion in 100 Hrs		Density, gm/cc	1.66 1.62
		Brisance, % TNT	118 114
<b>Flammability Index:</b>	Will not continue to burn	<b>Detonation Rate:</b>	
<b>Hygroscopicity:</b> %	0.03	Confinement	None
<b>Volatility:</b>		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.60
		Rate, meters/second	7385

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Tetrytol, 75/25

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones	(d)
Density, gm/cc	1.69	Hole Volume	127	
Charge Wt, lb	2.101	Hole Depth	120	
Total No. of Fragments:		Color:		
For TNT	703	Light yellow to buff		
For Subject HE	857	Principal Uses:		
3 inch HE, M42A1 Projectile, Lot KC-5:		Bursters, demolition blocks		
Density, gm/cc	1.60			
Charge Wt, lb	0.845			
Total No. of Fragments:		Method of Loading:		
For TNT	514	Cast		
For Subject HE	591			
Fragment Velocity: ft/sec		Loading Density: gm/cc		
At 9 ft		1.59		
At 25½ ft				
Density, gm/cc		Storage:		
Blast (Relative to TNT):		Method		
Air:		Dry		
Peak Pressure		Hazard Class (Quantity-Distance)		
Impulse		Class 9		
Energy		Compatibility Group		
Air, Confined:		Group I		
Impulse		Exudation		
Under Water:		Exudes at 65°C		
Peak Pressure				
Impulse		Eutectic Temperature, °C:		
Energy		67.5		
Underground:		gr Tetryl/100 gm TNT		
Peak Pressure		67.5°C		
Impulse		54.82		
Energy		Booster Sensitivity Test:		
		(c)		
		Condition		
		Tetryl, gm		
		Wax, in. for 50% Detonation		
		Density, gm/cc		
		100		
		1.65		
		1.66		

Tetrytol, 70/30

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<b>Composition:</b> %		<b>Molecular Weight:</b>	266
Tetryl	70	CO <sub>2</sub> %	-55
TNT	30	CO %	-13
C/H Ratio		<b>Density:</b> gm/cc	Cast 1.60
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	28	<b>Melting Point:</b> °C	68
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
Picatinny Arsenal Apparatus, in.	11	<b>Boiling Point:</b> °C	
Sample Wt, mg	18	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Steel Shoe	Unaffected	90°C	
Fiber Shoe	Unaffected	100°C	3.2
<b>Rifle Bullet Impact Test:</b> Trials	%	120°C	11+
Explosions	0	135°C	
Partials	55	150°C	
Burned	0	<b>200 Gram Bomb Sand Test:</b>	
Unaffected	45	Sand, gm	53.2
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	416	Minimum Detonating Charge, gm	
1	387	Mercury Fulminate	0.23*
5 Ignites	320	Lead Azide	0.22*
10	302	Tetryl	
15	289	*Alternative initiating charges.	
20	275	<b>Ballistic Mortar, % TNT:</b> (a)	120
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Treuxi Test, % TNT:</b>	
<b>100°C Heat Test:</b>		<b>Plate Dent Test:</b> (b)	
% Loss, 1st 48 Hrs	0.1	Method	B
% Loss, 2nd 48 Hrs	0.1	Condition	Cast
Explosion in 100 Hrs	None	Confined	Yes
<b>Flammability Index:</b> Will not continue to burn		Density, gm/cc	1.60
<b>Hygroscopicity:</b> %	0.02	Brisance, % TNT	117
<b>Volatility:</b>		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.60
		Rate, meters/second	7340

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Tetrytol, 70/30

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		<b>Glass Cones</b>	<b>Steel Cones</b>
Density, gm/cc	1.60	Hole Volume	
Charge Wt, lb	2.090	Hole Depth	
<b>Total No. of Fragments:</b>			
For TNT	703	<b>Color:</b> Light yellow to buff	
For Subject HE	840		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>			<b>Principal Uses:</b> Bursters, demolition blocks
Density, gm/cc	1.60		
Charge Wt, lb	0.842		
<b>Total No. of Fragments:</b>			<b>Method of Loading:</b> Cast
For TNT	514		
For Subject HE	585		
<b>Fragment Velocity: ft/sec:</b>			<b>Loading Density:</b> gm/cc 1.60
At 9 ft			
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>			<b>Storage:</b>
<b>Air:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Air, Confined:</b>			
Impulse			
<b>Under Water:</b>			
Peak Pressure			
Impulse			
Energy			
<b>Underground:</b>			
Peak Pressure			
Impulse			
Energy			

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Tetrytol, 65/35

<b>Composition:</b> %		<b>Molecular Weight:</b>	254
Tetryl	65	<b>Oxygen Balance:</b> CO <sub>2</sub> %	-56
TNT	35	CO %	-14
C/H Ratio		<b>Density:</b> gm/cc	1.60
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	28	<b>Melting Point:</b> °C	68
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
Picatinny Arsenal Apparatus, in.	11	<b>Boiling Point:</b> °C	
Sample Wt, mg	17	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	
		n <sub>20</sub> n <sub>25</sub> n <sub>30</sub>	
<b>Friction Pendulum Test:</b> Steel Shoe	Cracks	<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	2.8
<b>Rifle Bullet Impact Test:</b>	Trials	120°C	11+
	%	135°C	
Explosions	0	150°C	
Partials	10	<b>200 Gram Bomb Sand Test:</b>	
Burned	0	Sand, gm	52.6
Unaffected	90	<b>Sensitivity to Initiation:</b>	
<b>Explosion Temperature:</b> °C		Minimum Detonating Charge, gm	
Seconds, 0.1 (no cap used)		Mercury Fulminate	0.23*
1		Lead Azide	0.23*
5 Ignites	325	Tetryl	
10		*Alternative initiating charges.	
15		<b>Ballistic Mortar, % TNT:</b>	
20		<b>Treuzl Test, % TNT:</b>	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Plate Dent Test:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		Method	
% Loss, 2nd 48 Hrs		Condition	
Explosion in 100 Hrs		Confined	
<b>Flammability Index:</b> Will not continue to burn		Density, gm/cc	
<b>Hygroscopicity:</b> %	0.02	Brisance, % TNT	
<b>Volatility:</b>		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density gm/cc	1.60
		Rate, meters/second	7310

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Tetrytol, 65/35

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
90 mm HE, M71 Projectile, Lot WC-91:		(d)	(e)
Density, gm/cc	1.61	Gloss Cones	Steel Cones
Charge Wt, lb	2.010	Hole Volume	133 126
<b>Total No. of Fragments:</b>		Hole Depth	
For TNT	703	120	119
For Subject HE	856		
<b>3 inch HE, M42A1 Projectile, Lot KC-3:</b>		<b>Color:</b>	
Density, gm/cc	1.60	Light yellow to buff	
Charge Wt, lb	0.845		
<b>Total No. of Fragments:</b>		<b>Principal Uses:</b> Bursters, demolition blocks	
For TNT	514		
For Subject HE	585		
<b>Fragment Velocity: ft/sec</b>		<b>Method of Loading:</b>	
At 9 ft		Cp - t	
At 25½ ft			
Density, gm/cc			
<b>Blast (Relative to TNT):</b>		<b>Loading Density: gm/cc</b>	
Air:		1.60	
Peak Pressure			
Impulse			
Energy			
Air, Confined:		<b>Storage:</b>	
Impulse		Method	
Under Water:		Dry	
Peak Pressure		Hazard Class (Quantity-Distance)	
Impulse		Class 9	
Energy		Compatibility Group	
Underground:		Group I	
Peak Pressure		Exudation	
Impulse		Exudes at 65°C	
Energy			

Tetrytol, 80/20, 75/25, 70/30, 65/35Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, stainless steel, mild steel, mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

Wet: Stainless steel and mild steel coated with acid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutectic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

References:<sup>74</sup>

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 503, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.
- (e) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5723.

(f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

0	1	2	3	5	6	7	8	9
1260	1291	1372	1193	1285	1376	1477	1158	1379
1360	1311		1213	1325	1436	1737	1388	
1420	1451		1363	1885	1466	1797	1838	
1500	1651		1493	2125	1506			
1530	1951							

<sup>74</sup>See footnote 1, page 10.

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TNT (Trinitrotoluene)

<b>Composition:</b> % C 37.0 H 2.2 N 13.5 O 42.3 C/H Ratio 0.549		<b>Molecular Weight:</b> (C7H5N3O6) 227
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 95-100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14-15 Sample Wt, mg 17		<b>Oxygen Balance:</b> CO <sub>2</sub> % -74 CO % -25
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected		<b>Density:</b> gm/cc <b>Crystal</b> 1.65
<b>Rifle Bullet Impact Test:</b> Trials Explosions % 4 Partials 0 Burned 0 Unaffected 6		<b>Melting Point:</b> °C 91
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 570 1 520 5 Decomposes 475 10 465 15 20		<b>Freezing Point:</b> °C
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.04		<b>Boiling Point:</b> °C
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None		<b>Refractive Index, n<sub>D</sub></b> α 1.5430 β 1.6742 γ 1.717
<b>Flammability Index:</b> (b) 100		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.10 120°C 0.23 135°C 0.44 150°C 0.65
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.03		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.24* Lead Azide 0.27* <b>Tetryl</b> *Alternative initiating charges.
<b>Volatility:</b> 30°C Nil		<b>Ballistic Mortar, % TNT:</b> Std=100
		<b>Trouzi Test, % TNT:</b> Std=100
		<b>Plate Dent Test:</b> (a) Method A A B Condition Cast Pressed Cast Confined Yes Yes No Density, gm/cc 1.61 1.50 1.61 Brisance, % TNT 100 100 100
		<b>Detonation Rate:</b> Confinement Unconfined Unconfined Condition Pressed Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.56 1.56 Rate, meters/second 6825 6640

TNT (Trinitrotoluene)

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<b>Booster Sensitivity Test:</b>	(c)	<b>Decomposition Equation:</b>	(h)	(i)
Condition	Pressed	Oxygen, atoms/sec (Z/sec)	$10^{11.4}$	$10^{12.2}$
Tetryl, gm	100	Heat, kilocalorie/mole ( $\Delta H$ , kcal/mol)	34.4	43.4
Wax, in. for 50% Detonation	1.68	Temperature Range, °C	275-310	230-277
Wax, gm	0.82	Phase	Liquid	Liquid
Density, gm/cc	1.55			
<b>Heat of:</b>	(d)			
Combustion, cal/gm	3620			
Explosion, cal/gm	1080			
Gas Volume, cc/gm	730			
Formation, cal/gm	78.5			
Fusion, cal/gm	22.34			
Temperature, °C	79			
<b>Specific Heat:</b> cal/gm/°C				
0	0.309			
20	0.328			
50	0.353			
80	0.374			
<b>Burning Rate:</b>				
cm/sec				
<b>Thermal Conductivity:</b>				
cal/sec/cm/°C	See next page.			
<b>Coefficient of Expansion:</b>	(b)			
Linear, %/°C -40° to 60°C	$5.4 \times 10^{-5}$			
-40° to 60°C	$6.7 \times 10^{-5}$			
Volume, %/°C 27° to 80°C	$16 \times 10^{-5}$			
16° to 70°C	$26.3 \times 10^{-5}$			
(c)				
<b>Hardness, Mohs' Scale:</b>	(e)	1.4		
<b>Young's Modulus:</b>	(b)			
E', dynes/cm²	$5.45 \times 10^{10}$			
E, lb/inch²	$0.79 \times 10^6$			
Density, gm/cc	161			
<b>Compressive Strength:</b> lb/inch²	13800-14000			
Density, gm/cc	1.62			
<b>Vapor Pressure:</b>	(f)			
'C	mm Mercury			
50	0.042			
85	0.053			
90	0.067			
95	0.085			
100	0.106			

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### TNT (Trinitrotoluene)

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M471 Projectile, Lot WC-91:</b>		Giant Cones	Steel Cones
Density, gm/cc	1.60	Hole Volume	100
Charge Wt, lb	2.104	Hole Depth	100
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Light yellow	
For Subject HE	703		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Principles of Use:</b>	
Density, gm/cc	1.60	GP bombs, HE projectiles, demolition charges, depth charges, grenades, propellant compositions	
Charge Wt, lb	0.848		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT	514	1. Cast	
For Subject HE	514	2. Pressed	
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft	(k)	See below	
At 25½ ft	2000		
Density, gm/cc	23.0		
	1.58		
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
<b>Air:</b>		<b>Method</b>	
Peak Pressure	100	Dry	
Impulse	100		
Energy	100		
<b>Air, Confined:</b>		<b>Hazard Class (Quantity-Distance)</b>	
Impulse	100	Class 9	
<b>Under Water:</b>		<b>Compatibility Group</b>	
Peak Pressure	100	Group I	
Impulse	100		
Energy	100		
<b>Underground:</b>		<b>Exudation</b>	
Peak Pressure	100	None at 65°C	
Impulse	100		
Energy	100		
<b>Loading Density: gm/cc</b>		<b>Thermal Conductivity:</b>	
1. Cast 1.58-1.59		1. Cast 1.58-1.59 2. Pressed psi x 10 <sup>3</sup>	
3	5	10	15
1.35	1.40	1.45	1.52
			1.55
			1.59
			1.6
<b>Temperature (25°-30°):</b>		<b>Viscosity, poises:</b>	
cal/sec/cm/ <sup>2</sup> /°C		Tem., 85°C	
		100°C	
Density 1.19 gm/cc (g) 5.28 x 10 <sup>-4</sup>		0.139	
1.51 gm/cc (g) 7.12 x 10 <sup>-4</sup>		0.095	
1.54 gm/cc (b) 5.6 x 10 <sup>-4</sup>			
1.67 gm/cc (s) 12.21 x 10 <sup>-4</sup>			
<b>Bulk Modulus at Room Temperature (25°-30°):</b>		<b>(m)</b>	
Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>		2.92	
Density, gm/cc		1.56	

TNT (Trinitrotoluene)

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Effect of Temperature on Rate of Detonation: (1)

Temperature of Charge, °C	-54	21	60	60
Hours at Temperature	16	16	24	72
Density, gm/cc	1.63	1.62	1.64	1.64
Rate, meters/second	6700	6820	6770	6510

Sensitivity to Electrostatic Discharge, Joules; Through 100 Mesh:

Unconfined	0.36
Confined	4.4

Impact Sensitivity versus Temperature:

Picatinny Arsenal Apparatus, 2 kg wt, inches:

°C	inches
-40	17
Rock	14
80	7
90	3
105-110	2 (5 expl in 20 trials)

Impact Sensitivity versus Loading Method, Large Impact Apparatus, Inches:

Pressed at 1.60 gm/cc	70
Cast at 1.60 gm/cc	26

Rifle Bullet Impact Sensitivity versus Temperature, Confinement:

Standard Iron Bomb:	Room	105° to 110°C
	Temperature	
No Air Space		
Trials	10	10
Explosions	1 very low order	7
Air Space		
Trials	10	10
Explosions	0	0
Tin or Cardboard Bombs:		
With or Without Air Space		
Trials	10	10
Explosions	0	0

TNT (Trinitrotoluene)Explosion Temperature versus TNT Initial Temperature:TNT Temperature, InitialExplosion Temperature, °C

Room  
105°-100°<sup>o</sup>C

470 (Decomposes)  
480 (Decomposes)

Explosion Temperature versus Confinement, °C:

Unconfined	Decomposes	470
Sealed in glass capillary	Explodes	320-335

Viscosity at 80.5°<sup>o</sup>C:

Viscosity,  $\eta$ , cp  $\log \eta = 2.046 S + 1.26$   
 $S = \frac{1}{2}$  solid in slurry  
 Particle size effect, small

Density, gm/cc:

°C	State	gm/cc
27 to 70	Flaked	1.65
80	Flaked	1.64
82	Liquid	1.48
87	Liquid	1.48
95	Liquid	1.47

Solubility of TNT, gm/100 gm (%), in: (r)

Water		Acetone		Benzene		Toluene	
°C	%	°C	%	°C	%	°C	%
0	0.0100	0	57	0	13	0	28
20	0.0130	20	109	20	67	20	55
40	0.0285	40	228	40	180	40	130
60	0.0675	60	600	60	478	60	367
				80	>2000	80	>1700

Carbon tetrachloride		Ether		Chloroform		Trichloroethylene	
°C	%	°C	%	°C	%	°C	%
0	0.20	0	1.73	0	6	25	3.5
0	0.55	20	3.29	20	19	55	60
40	1.75			40	66		
60	6.90			60	302		
70	17.34						
75	24.35						

TNT (Trinitrotoluene)

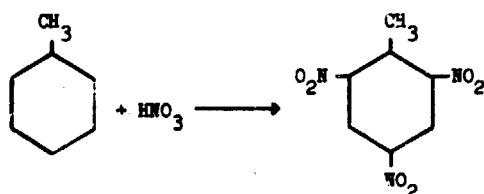
<u>Pyridine</u>	<u>Methyl acetate</u>	<u>Ethylene dichloride</u>	<u>o-Pchoxy-ethoxy-acetate</u>
<u>°C</u>	<u>°C</u>	<u>°C</u>	<u>°C</u>
20 140	20 73	20 34	20 29.5
40 250	50 135	40 123	40 19
60 640	50 280	60 460	50 96
70 1250			

<u>Tetrachloro-ethane</u>	<u>Aniline</u>	<u>Isopropyl alcohol</u>	<u>Ethanol</u>
<u>°C</u>	<u>°C</u>	<u>°C</u>	<u>°C</u>
20 18	10 6.1	20 0.76	20 0.62
40 50	30 11.5	40 1.96	40 1.25
50 100	50 29	50 2.95	60 2.85
	70 74		60 8.4
	80 130		70 15

<u>Isobutyl alcohol</u>	<u>Carbon disulfide</u>	<u>Chlorobenzene</u>
<u>°C</u>	<u>°C</u>	<u>°C</u>
0 0.20	0 0.14	20 35
20 0.61	20 0.44	30 51
40 1.41	40 1.4	40 79
50 2.35		50 116

Preparation.(AC 7258, 7259, 7260 - Nitration Kinetics)  
(Chemistry of Powder and Explosives, Davis)

In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than 6¢/lb. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also count current, MNT was nitrated to TNT.

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion ( $\text{NO}_2^+$ ), on the one hand, and the role of the bisulfate ion ( $\text{HSO}_4^-$ ) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$$\frac{d(\text{TNT})}{dt} = K(\text{NO}_2^+) [K'(\text{HSO}_4^-) + K''(\text{H}_2\text{SO}_4)] (\text{DNT})$$

Three Stage Process: Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 29 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at  $30^\circ\text{-}40^\circ\text{C}$ , with good agitation. Acid addition requires 1-1.5 hour, and stirring at  $30^\circ\text{-}40^\circ\text{C}$  is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to  $50^\circ\text{C}$  and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between  $90^\circ$  and  $100^\circ\text{C}$ . Acid addition requires 1 hour, and stirring at  $90^\circ\text{-}100^\circ\text{C}$  is continued 2 more hours.

While the dinitration mixture is still at  $90^\circ\text{C}$ , 145 gm fuming sulfuric acid (oleum containing 15% free  $\text{SO}_3$ ) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% oleum is slowly added, under good agitation at  $100^\circ\text{-}110^\circ\text{C}$  over 1½ hours. The mixture is stirred at  $100^\circ\text{-}115^\circ\text{C}$  for 2 more hours, cooled, filtered, and the TNT cake broken up and washed with water. The TNT is washed 3-4 times with hot water ( $85^\circ\text{-}95^\circ\text{C}$ ) with good agitation. The product can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at  $90^\circ\text{C}$  for  $\frac{1}{2}$  hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

#### Origin:

TNT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by Beilstein and Kuhlberg (Ber 3, 202 (1870)) and also Tiemann (Ber 3, 217 (1870)), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind, 1891, p. 1028). After 1901 TNT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TNT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthetic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TNT for melt-loading, and its extensive use in binary and ternary explosive mixtures, TNT is considered the most important military explosive known today.

#### Destruction by Chemical Decomposition:

TNT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide ( $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ ) in 6 parts of water.

#### References:<sup>75</sup>

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

<sup>75</sup>See footnote 1, page 10.

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- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetralyl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (e) Report AC-2587.
- (f) International Critical Tables and various other sources in the open literature.
- (g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2801, First Report, August 1942.
- (h) A. J. B. Robertson, Trans Farad Society, 44: 977 (1948).
- (i) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.
- (j) Committee of Div 2 and 8, NDRC, Report on HPX and Tritonal, OSRD No. 5406, 31 July 1945.
- (k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
- (l) W. J. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2303, November 1956.
- (m) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.
- (n) Kuntrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.
- (o) Also see the following Picatinny Arsenal Technical Reports on TNT:

0	1	2	3	4	5	6	7	8	9
10	291	132	43	364	65	86	47	118	99
30	551	582	83	694	195	266	87	283	249
240	731	782	133	874	425	556	507	638	269
350	861	892	273	904	555	666	527	738	319
630	891	972	513	1094	695	956	597	768	389
760	901	1072	643	1104	735	986	707	838	499
810	971	1182	673	1124	805	1046	807	1088	709
1120	1041	1192	743	1224	975	1146	817	1098	739
1140	1121	1272	853	1284	1145	1276	937	1128	779
1170	1311	1292	863	1294	1155	1376	1107	1143	799
1260	1391	1342	1063	1304	1225	1446	1147	1158	889
1270	1431	1352	1123	1314	1285	1466	1217	1188	929
1360	1451	1372	1133	1344	1305	1476	1247	1198	939
1400	1491	1402	1193	1474	1315	1556	1307	1228	1099
1460	1651	1452	1243	1444	1395	1636	1417	1258	1109
1500	1821	1472	1323	1454	1425	1756	1427	1308	1129

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TNT (Trinitrotoluene)

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1530	1492	1373	1524	1435	1956	1437	1318	1139
1540	1562	1493	1544	1445	2236	1457	1338	1179
1550	1582	1553	1564	1495		1497	1388	1199
1730	1712	1633	1604	1515		1537	1418	1259
2010	1862	1693	1674	1535		1547	1428	1289
2100		1823	1754	1585		1557	1578	1339
2160		2063	1924	1605		1577	1618	1369
		2163	2064	1635		1597	1688	1379
			2214	1665		1677	1728	1419
				1865		1737	1828	1429
				1965		1797	1838	1469
				1715		1827	1858	1489
				1885		1847	2008	1529
				2125		2007	2138	1549
				2175		2147	2168	1629
						2167		1689
								1709
								1729
								1749
								1809
								1819
								1879
								1949
								2159
								2179

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<b>Composition:</b> %		<b>Molecular Weight:</b>	97
RDX	42	Oxygen Balance: CO <sub>2</sub> %	-55
TNT	40	CO %	-26
Aluminum	18	<b>Density:</b> gm/cc	Cast 1.76-1.81
C/H Ratio		<b>Melting Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	42	<b>Boiling Point:</b> °C	
Sample Wt 20 mg		Refractive Index, n <sub>D<sup>20</sup></sub>	
Picatinny Arsenal Apparatus, in.	9	n <sub>D<sup>20</sup></sub>	
Sample Wt, mg	15	n <sub>D<sup>20</sup></sub>	
<b>Friction Pendulum Test:</b> Steel Shoe		<b>Vacuum Stability Test:</b> cc/40 Hrs, at	
Fiber Shoe		90°C	
<b>Rifle Bullet Impact Test:</b> Trials		100°C	
Explosions %	20	120°C	1.0
Partials	80	135°C	
Burned	0	150°C	
Unaffected	0	<b>200 Gram Bomb Sand Test:</b> Sand, gm	59.5
<b>Ignition Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.18
5 Decomposes	260	Lod Azide	
10		Tetryl	
15		<b>Ballistic Mortar, % TNT:</b> (a)	138
20		<b>Treves Test, % TNT:</b> (b)	164
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Plate Dent Test:</b> (c)	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	0.00	Method	R
% Loss, 2nd 48 Hrs	0.10	Condition	Cast
Explosion in 100 Hrs	None	Confined	No
<b>Flammability Index:</b>	196	Density, gm/cc	1.83
<b>Hygroscopicity:</b> % 30°C, 90% RH	0.00	Brisance, % TNT	120
<b>Volatility:</b>		<b>Detonation Rate:</b> (d)	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.81
		Rate, meter./second	7495

<b>Booster Sensitivity Test:</b>	(c)		<b>Decomposition Equation:</b>
Condition	Pressed	Cas c	Oxygen, atoms/sec (Z/sec)
1-Ethyl, gm	10	5	Heat, kilocalories/mole (ΔH, kcal/mol)
Wax, in. for 50% Detonation			Temperature Range, °C
Wax, gm	2	0	Phase
Density, gm/cc	1.64	1.81	
<b>Heat of:</b>	(a)		
Combustion, cal/gm		3740	
Explosion, cal/gm		1800	
Gas Volume, cc/gm			
Formation, cal/gm			
Fusion, cal/gm			
<b>Specific Heat: cal/gm/°C</b>	(b)		
At -5°C		0.22	
Density, gm/cc		1.82	
At 15°C		0.24	
<b>Burning Rate:</b>			
cm/sec			
<b>Thermal Conductivity:</b>	(b)		
cal/sec/cm/°C		$9.7 \times 10^{-4}$	
Density, gm/cc		1.82	
<b>Coefficient of Expansion:</b>			
Linear, %/°C -73 to 75°C $4.7 \times 10^{-5}$	(b)		
<b>Volume, %/°C</b>			
<b>Hardness: Mohs Scale:</b>			
<b>Young's Modulus:</b>	(b)		
E', dynes/cm <sup>2</sup>		$9.53 \times 10^{10}$	
E, lb/inch <sup>2</sup>		$1.38 \times 10^6$	
Density, gm/cc		1.77	
<b>Compressive Strength: lb/inch<sup>2</sup></b>	(b)	2100-2300	
Density, gm/cc		1.77	
<b>Vapor Pressure:</b>			
°C		mm Mercury	
<b>Armor Plate Impact Test:</b>			
60 mm Mortar Projectile:			(e)
50% Inert, Velocity, ft/sec			185
Aluminum Fineness			
<b>500-lb General Purpose Bomb:</b>			
Plate Thickness, inches			
1			
1 1/4			
1 1/2			
1 3/4			
<b>Bomb Drop Test:</b>			
<b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>			
Max Safe Drop, ft			
<b>500-lb General Purpose Bomb vs Concrete:</b>			
Height, ft			
Trials			
Unaffected			
Low Order			
High Order			
<b>1000-lb General Purpose Bomb vs Concrete:</b>			
Height, ft			
Trials			
Unaffected			
Low Order			
High Order			

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<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100: 50/36.5/13.5</b>	
90 mm HE, M71 Projectile, Lot WC-C1:		Glass Cones	Steel Cones
Density, gm/cc	1.75	150	145
Charge Wt, lb	2.316	127	131
<b>Total No. of Fragments:</b>		<b>Color:</b>	
For TNT	703	Gray	
For Subject HE	891		
3 inch HE, M42A1 Projectile, Lot KC-S:		<b>Principal Uses:</b> Depth charges, bombs	
Density, gm/cc	1.79		
Charge Wt, lb	0.940		
<b>Total No. of Fragments:</b>		<b>Method of Loading:</b>	
For TNT	514	Cast	
For Subject HE	647		
<b>Fragment Velocity: ft/sec</b>		<b>Loading Density: gm/cc</b>	
At 9 ft	2960	1.76-1.81	
At 23½ ft	2800		
Density, gm/cc	--		
<b>Blast (Relative to TNT):</b>		<b>Storage:</b>	
(e)		Method	Dry
Air:		Hazard Class (Quantity-Distance)	Class 9
Peak Pressure	122	Compatibility Group	Group I
Impulse	125		
Energy	146		
Air, Confined:			
Impulse	116		
Under Water:		<b>Effect of Temperature on Impact Sensitivity:</b>	
Peak Pressure	116	Temp, °C	PA Impact Test 2 Kg Wt, inches
Impulse	127	25	15
Energy	153	32	7
		104	8
<b>Underground:</b>		<b>Viscosity, poises:</b>	
Peak Pressure		Temp, 83°C	4.5
Impulse		95°C	2.3
Energy			

TorpexPreparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDX is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued stirring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDX/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Torpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in service munitions:

	<u>Torpex 2 unwaxed</u>	<u>Torpex 2 waxed</u>	<u>Torpex 3</u>
	(a)	(b)	(c)
RDX, %	42	41.6	41.4
TNT, %	40	39.7	39.5
Aluminum, %	18	18.0	17.9
Wax, %		0.7	0.7
Calcium chloride, %			0.5

- (a) Made from Composition B-2 or 60/40 Cyclotol.
- (b) Made by the addition of aluminum to Composition B.
- (c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to coagulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.66-1.70 for waxed torpex, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torpex. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References:<sup>76</sup>

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
  - (b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
  - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

<sup>76</sup>See footnote 1, page 10.

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(d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.

(e) J. C. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1946.

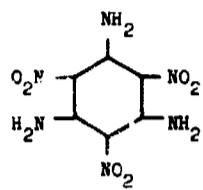
(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NIRC Contract W572-ORD-5723.

(g) Also see the following Picatinny Arsenal Technical Reports on Torpex:

0	1	2	3	4	5	6	7	8
1530	1651	1292	2353	1585 1635 1885 2355	1796	1797	1838	

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1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)

<b>Composition:</b> %		<b>Molecular Weight:</b> $(C_6H_6N_6O_6)$ 258
C 27.9		Oxygen Balance: CO <sub>2</sub> % -56
H 2.3		CO % -19
N 32.6		Density: gm/cc Crystal 1.93
O 37.2		Melting Point: °C 330 (b, e) 360 (a)
C/H Ratio 0.302		Frosting Point: °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg		Boiling Point: °C
Picatinny Arsenal Apparatus, in. Sample Wt, mg	11 7	Refractive Index, n <sub>d20</sub> n <sub>d25</sub> n <sub>d30</sub>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe		<b>Vacuum Stability Test:</b> cc/40 Hr., at 90°C ---- 100°C (a, b) 0.36 120°C ---- 135°C ---- 150°C ----
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm 42.9
<b>Explosion Temperature:</b> °C Seconds 0.1 (no cap used) 1 5 10 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Brilliantin Meter, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		<b>Crossed Test, % TNT:</b>
<b>Flammability Index:</b>		<b>Plate Dowd Test:</b> Method Condition Continued Density, gm/cc Brisance, % TNT
<b>Hygrosc., Jelly:</b> %		
<b>Volatility:</b>		<b>Detonation Rate:</b> Co. Increment None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.80 Rate, meters/second 7500

1,3,5-Triamino-2,4,6-Tinitrobenzene (TATNB)

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<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-8: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE  <b>Fragment Velocity: ft/sec:</b> At 9 ft At 25½ ft Density, gm/cc		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth  Color:                  Yellow  <b>Principal Uses:</b>    <b>Method of Loading:</b> Pressed  <b>Loading Density: gm/cc</b> At 50,000 psi                  1.80  <b>Storage:</b> Method                  Dry  <b>Hazard Class (Quantity-Distance):</b>  <b>Compatibility Group:</b>  <b>Exudation:</b>  <b>Detonation Velocity:</b> (a, b, c)  <b>Density, gm/cc</b> <b>Meters/sec</b> 1.290                  5380 1.345                  5628 1.675                  6550 1.675                  6575 1.882                  7035 1.835                  7220  <b>Heat of:</b> Explosion, cal/gm                  2831	
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1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)Preparation:

(a)

Absolute alcohol (200 milliliters) was saturated with ammonia and then 22.5 gm (0.028 mol) of 1,3,5-tribromo-2,4,6-trinitrobenzene, prepared according to Hill (NAVORD Report No. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional ammonia was bubbled into the mixture, which was then heated under reflux for thirty minutes, filtered hot, and the insoluble product collected on a Buchner funnel. The product was washed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallized from nitrobenzene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATNB. Since it did not seem feasible to develop a new method of preparation, an investigation was made of the reported amination reactions (see Origin below). An attempt was made (Ref 1) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref 2): 1,3,5-trichlorobenzene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobenzene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATNB, in yields of at least 95%.

Origin:

TATNB was prepared for the first time in 1888 by C. L. Jackson and J. P. Wing, who found the compound insoluble in alcohol, ether, chloroform, benzene, and glacial acetic acid; and soluble in nitrobenzene and aniline (Amer Chem Journal 10, 282 (1888)). B. Flurschheim and E. L. Holmes prepared TATNB from benzene free pentanitroaniline by gradually adding it to 10% aqueous ammonia (J Chem Soc, Pt 2, 345 (1928)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and Wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATNB to hex-aminobenzene. Either decomposition occurred or a hydrochloride of penta-aminobenzene was formed. Flurschheim and Holmes succeeded in reducing TATNB with p-aminobenzoquinazine by heating them together up to 200°C (J Chem Soc, Pt 1, 334 (1929)) (Bull 1, 301 and KIJ, 147).

References:<sup>77</sup>

- (a) F. Taylor, Jr., Synthesis of New High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzene, NAVORD Report No. 4405, 1 November 1956.
- (b) L. D. Hampton, Small Scale Detonation Velocity Measurements from May 1951 to May 1954, NAVORD Report No. 3731, June 1954.
- (c) E. M. Fisher and E. A. Christian, Explosion Effects Data Sheets, NAVORD Report No. 2986, 14 June 1955.

<sup>77</sup>See footnote 1, page 10.

Triethylene Glycol Dinitrate (TGN) Liquid

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<b>Composition:</b>		<b>Molecular Weight: (C<sub>6</sub>H<sub>12</sub>N<sub>2</sub>O<sub>8</sub>) 240</b>	
% C	29.9	CH <sub>2</sub> ONO <sub>2</sub>	
% H	5.4	H <sub>2</sub> C	
% N	11.7	— O —	
% O	53.0	H <sub>2</sub> C	
C/H Ratio 0.177		CH <sub>2</sub> ONO <sub>2</sub>	
<b>Impact Sensitivity, 2 Kg Wt:</b>			
Bureau of Mines Apparatus, cm	100+		
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.	43		
Sample Wt, mg			
<b>FriCTION Pendulum Test:</b>		<b>Boiling Point: °C</b>	
Steel Shoe	Unaffected	20°C	1.33
Fiber Shoe	Unaffected	25°C	1.32
<b>R/M Bullet Impact Test:</b>		<b>Refractive Index, n<sub>D</sub></b>	
Trials	%	n <sub>D</sub>	1.4540
Explosions		n <sub>D</sub>	
Partials		n <sub>D</sub>	
Burned			
Unaffected			
<b>200 Gram Bomb Sand Test:</b>		<b>Vacuum Stability Test:</b>	
Sand, gm		cc/40 Hrs, at	
		90°C	
		100°C	0.45
		120°C	8 hours 0.8
		135°C	
		150°C	
<b>75°C International Heat Test:</b>		<b>Sensitivity to Initiators:</b>	
% Loss in 48 Hrs		Minimum Detonating Charge, gm	
		Mercury Fulminate	
		Lead Azide	
		Tetryl	
<b>100°C Heat Test:</b>		<b>Ballistic Mortar, % TNT:</b>	
% Loss, 1st 48 Hrs	1.8		
% Loss, 2nd 48 Hrs	1.6		
Explosion in 100 Hrs	None		
<b>Flammability Index:</b>		<b>Plate Dent Test:</b>	
		Method	
		Condition	
		Confined	
		Density, gm/cc	
		Brisance, % TNT	
<b>Hygroscopicity: %</b>		<b>Detonation Rate:</b>	
		Confinement	Shelby steel
		Condition	Liquid
		Charge Diameter, in.	1.25
		Density, gm/cc	1.33
		Rate, meters/second	Fails
<b>Volatility: 60°C, mg/cm<sup>2</sup>/hr</b>			
	40		

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Triethylene Glycol Dinitrate (TGN) Liquid

<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Gloss Cones      Steel Cones Hole Volume Hole Depth  Color:	
3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Principal Uses:</b> Ingredient of rocket and double base propellants  <b>Method of Loading:</b>	
<b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc		<b>Loading Density:</b> gm/cc  <b>Storage:</b>	
<b>Eject (Relative to TNT):</b>  Air: Peak Pressure Impulse Energy		<b>Hazard Class (Quantity-Distance)</b>  <b>Compatibility Group</b>  <b>Exudation</b>	
<b>Air, Confined:</b> Impulse		<b>Solubility in Water,</b> gm/100 gm, at: 25°C                    0.55 60°C                    0.68	
<b>Under Water:</b> Peak Pressure Impulse Energy		<b>Solubility, gm/100 gm,</b> at 25°C, in: Ether                    = Alcohol                 = 2:1 Ether:Alcohol     = Acetone                =	
<b>Underground:</b> Peak Pressure Impulse Energy		<b>Viscosity, centipoises:</b> Temp, 20°C            13.2 <b>Hydrolysis, % Acid:</b> 10 days at 22°C      0.032 5 days at 60°C        0.02	
<b>Heat of:</b>  Combustion, cal/gm    3428 Explosion, cal/gm     357 Gas Volume, cc/gm    851		<b>Vapor Pressure:</b> 0°C                    mm Mercury 25                    < 0.001	

Triethylene Glycol Dinitrate (TEGN) Liquid

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Origin:

Lourenco prepared triethylene glycol in 1863 by heating glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Wurtz prepared triethylene glycol by heating ethylene oxide with glycerine at 100°C. By action of nitric acid triethylene glycol was oxidized to  $(H_2OOC\cdot CH_2\cdot O\cdot CH_2)_2$  (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Viergeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at 0 ± 5°C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at 0 ± 5°C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ice and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The etheral solution is water-washed until it has the same pH value as distilled water. It is carefully separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

References:<sup>78</sup>

- (a) See the following Picatinny Arsenal Technical Reports on TEGN:

3	5	6	7	8
1953	1745	1786	1767	1638
2193		2056	1817	

<sup>78</sup>See footnote 1, page 10.

Trimonite

<b>Composition:</b> %		<b>Molecular Weight:</b>	217
Picric Acid	88 - 90	Oxygen Balance:	
Mononitronaphthalene	12 10	CO <sub>2</sub> %	.62
		CO %	.14
<b>C/H Ratio</b>		<b>Density:</b> gm/cc	Cast 1.60
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm	60	<b>Melting Point:</b> °C	90
Sample Wt 20 mg		<b>Freezing Point:</b> °C	
Picatinny Arsenal Apparatus, in.	10	<b>Boiling Point:</b> °C	Explodes 300
Sample Wt, mg		<b>Refractive index, n<sub>20</sub><sup>D</sup></b>	
<b>Friction Pendulum Test:</b> Steel Shoe		n <sub>25</sub> <sup>D</sup>	
<b>Rifle Bullet Impact Test:</b> Trials	%	n <sub>30</sub> <sup>D</sup>	
Explosions	0	<b>Vacuum Stability Test:</b>	
Partials	0	cc/40 Hrs, at	
Burned	0	90°C	
Unaffected	100	100°C	
		120°C	0.9
		135°C	
		150°C	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used)		<b>200 Gram Bomb Sand Test:</b>	
1		Sand, gm	44.2
5 Decomposes	315	<b>Sensitivity to Initiation:</b>	
10		Minimum Detonating Charge, gm	
15		Mercury Fulminate	
20		Lod Azide	0.20
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		Tetryl	0.04
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs		<b>Ballistic Mortar, % TNT:</b>	
% Loss, 2nd 48 Hrs		<b>Trexal Test, % TNT:</b>	
Explosion in 100 Hrs		<b>Plate Dent Test:</b>	
<b>Flammability Index:</b>		Method	
<b>Hygrosopicity:</b> %		Condition	
<b>Volatility:</b>		Confined	
		Density, gm/cc	
		Brisance, % TNT	
		<b>Detonation Rate:</b>	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.60
		Rate, meters/second	7020

Trimonite

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<b>Fragmentation Test:</b>	
90 mm HE, M71 Projectile, Lot WC-91:	<b>Shaped Charge Effectiveness, TNT = 100:</b>
Density, gm/cc	Glass Cones      Steel Cones
Charge Wt, lb	Hole Volume
Total No. of Fragments:	Hole Depth
For TNT	
For Subject HE	
3 inch HE, M42A1 Projectile, Lot KC-5:	<b>Color:</b>
Density, gm/cc	Principal Uses: TNT substitute in projectiles
Charge Wt, lb	and bombs
Total No. of Fragments:	
For TNT	<b>Method of Loading:</b> Cast
For Subject HE	
<b>Fragment Velocity: ft/sec</b>	<b>Loading Density: gm/cc</b> 1.60
At 9 ft	
At 25½ ft	
Density, gm/cc	
<b>Blast (Relative to TNT):</b>	<b>Storage:</b>
Air:	Method Dry
Peak Pressure	
Impulse	
Energy	
Air, Confined:	Hazard Class (Quantity-Distance) Class 9
Impulse	
Under Water:	Compatibility Group Group I
Peak Pressure	
Impulse	
Energy	Exudation Exudes at 50°C
Underground:	<b>Preparation:</b>
Peak Pressure	Picric acid and alpha-mononitronaphthalene
Impulse	are melted together in an aluminum or tin steam-
Energy	jacketed melt kettle equipped with a stirrer.
	Although picric acid alone requires a high tem-
	perature for its melt loading (120°C), the
	mixture forms a eutectic melting at 49°C. Care
	must be taken to prevent the formation of dan-
	gerous metallic picrates. Trimonite is of
	interest as an emergency substitute for TNT.

TrimoniteOrigin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TNT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comparatively inexpensive substitute for TNT.

References: <sup>79</sup>

- (a) See the following Picatinny Arsenal Technical Reports on Trimonite:

2	5	6	8
1352	1325	926	1098
1372		976	1836

<sup>79</sup>See footnote 1, page 10.

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

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<b>Composition:</b> % C 18.6 H 1.6 N 21.8 O 58.0 C/H Ratio 0.202 	<b>Molecular Weight:</b> $(C_6H_6N_6O_{14})$ 366	
	<b>Oxygen Balance:</b> CO <sub>2</sub> % -4.2 CO % 20.8	
	<b>Density:</b> gm/cc Form I 1.78	
	<b>Melting Point:</b> °C 93	
	<b>Freezing Point:</b> °C	
	<b>Boiling Point:</b> °C	
	<b>Refractive Index:</b> $n_D^{20}$ Form I (e) <u>Crystal Axis</u> α 1.518 β 1.527 γ 1.546	
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 48 hrs 0.60 120°C 135°C 150°C	
	<b>200 Gram Bomb Sand Test:</b> Sand, gm	
	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 50% point, cm (a) 20	<b>Ballistic Mortar, % TNT:</b> (b) 136	
	<b>Trenzi Test, % TNT:</b>	
	<b>Plate Dent Test:</b> Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
	<b>Detonation Rate:</b>	
	Confinement	
	Condition	
<b>Flammability Index:</b>  <b>Hygrosopicity:</b> % 30°C, 90% RH 0.00 75°C, 5 months N/A (a)	Charge Diameter, in.	
	Density, gm/cc 1.60	1.76
	Rate, meters/second 7760	8290
<b>Volatility:</b>		

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2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

<b>Booster Sensitivity Test:</b>	<b>Decomposition Equation:</b>	
Condition	Oxygen, atoms/sec (Z/sec)	$4.4 \times 10^{21}$
Tetryl, gm	Heat, kilocalories/mole ( $\Delta H$ , kcal/mol)	43.4
Wax, in. for 50% Detonation	Temperature Range, °C	
Wax, gm	Phase	Liquid
Density, gm/cc		
 <b>Heat of:</b>	 <b>Armer Plate Impact Test:</b>	
Combustion, cal/gm	60 mm Mortar Projectile: 50° Inert, Velocity, ft/sec	
Explosion, cal/gm	Aluminum Fineness	
Gas Volume, cc/gm		
Formation, cal/gm	 <b>500-lb General Purpose Bomb:</b>	
Fusion, cal/gm	Plate Thickness, inches	
Sublimation, cal/gm (e. t.)	1	
Specific Heat: cal/gm/°C	1 1/4	
	1 1/2	
	1 3/4	
 <b>Burning Rate:</b>	 <b>Bomb Drop Test:</b>	
cm/sec	T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:	
 <b>Thermal Conductivity:</b>	Max Safe Drop, ft	
cal/sec/cm/°C	300-lb General Purpose Bomb vs Concrete:	
 <b>Coefficient of Expansion:</b>	Height, ft	
Linear, %/°C	Trials	
 <b>Volume, %/°C</b>	Unaffected	
 <b>Hardness, Mohs' Scale:</b>	Low Order	
 <b>Young's Modulus:</b>	High Order	
E', dynes/cm <sup>2</sup>	 <b>1000-lb General Purpose Bomb vs Concrete:</b>	
E, lb/inch <sup>2</sup>	Height, ft	
Density, gm/cc	Trials	
 <b>Compressive Strength:</b> lb/inch <sup>2</sup>	Unaffected	
 <b>Vapor Pressure:</b> (e)	Low Order	
°C	High Order	
65	mm Mercury	
75	$3.3 \times 10^{-4}$	
85	$1.3 \times 10^{-4}$	
100	$4.2 \times 10^{-3}$	
120	$2.3 \times 10^{-2}$	
	$1.4 \times 10^{-2}$	

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

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<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot KC-9:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p> <p><b>Blast (Relative to H-6):</b>      <u>Sphere</u>      <u>Cylinder (h)</u></p> <table border="1"> <tr><td>Air: 1-lb Charge:</td><td>EW*</td><td>EV*</td><td>EW*</td><td>EV*</td></tr> <tr><td>Peak Pressure</td><td>0.91</td><td>0.84</td><td>0.81</td><td>0.75</td></tr> <tr><td>Impulse</td><td>0.73</td><td>0.67</td><td>0.74</td><td>0.69</td></tr> <tr><td>Energy</td><td></td><td></td><td></td><td></td></tr> </table> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p>*EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.</p>	Air: 1-lb Charge:	EW*	EV*	EW*	EV*	Peak Pressure	0.91	0.84	0.81	0.75	Impulse	0.73	0.67	0.74	0.69	Energy					<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr><th>Glass Cones</th><th>Steel Cones</th></tr> </thead> <tbody> <tr><td>Hole Volume</td><td></td></tr> <tr><td>Hole Depth</td><td></td></tr> </tbody> </table> <p><b>Color:</b> Colorless</p> <p><b>Principal Uses:</b></p> <p><b>Method of Loading:</b></p> <table border="1"> <tr><td>Loading Density: gm/cc</td><td>Form I</td><td>1.783</td></tr> <tr><td></td><td>Form II</td><td>1.677</td></tr> <tr><td></td><td>Liquid, 99°C</td><td>1.551</td></tr> </table> <p><b>Storage:</b></p> <table border="1"> <thead> <tr><th>Method</th><th>Wet</th></tr> </thead></table> <p><b>Hazard Class (Quantity-Distance):</b></p> <p><b>Compatibility Group:</b></p> <p><b>Exudation:</b></p> <p><b>Bruceton Safety Test Results: (g)</b></p> <p>Mean and standard deviation of lengths of 0.300 diameter cylinder across which initiation is possible for 50% certainty:</p> <table border="1"> <tr><td>TNT</td><td>0.391</td><td>± 0.040</td></tr> <tr><td>RDX Comp B</td><td>0.381</td><td>± 0.042</td></tr> <tr><td>TNETB</td><td>0.920</td><td>± 0.059</td></tr> </table> <p><b>Absolute Viscosity, poises: (e)</b></p> <table border="1"> <tr><td>Temp, 98.9°C</td><td>0.173</td></tr> <tr><td>106.5°C</td><td>0.138</td></tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth		Loading Density: gm/cc	Form I	1.783		Form II	1.677		Liquid, 99°C	1.551	Method	Wet	TNT	0.391	± 0.040	RDX Comp B	0.381	± 0.042	TNETB	0.920	± 0.059	Temp, 98.9°C	0.173	106.5°C	0.138
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2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNTB)Solubility (Room Temperature):

(a)

Solvent	Solubility
Water	Insoluble
n-Hexane	Insoluble
Carbon tetrachloride	Insoluble
Ethanol	5 gm/100 gm solvent
Chloroform	5 gm/100 gm solvent
Benzene	10 gm/100 gm solvent
Nitromethane	Very soluble
Glacial acetic acid	Very soluble
Ethyl acetate	Very soluble

TNTB Forms Eutectics With the Following Compounds:

(a)

TNT	57
PTNES (bis(trinitroethyl) succinate)	80+
PTNEN (bis(trinitroethyl) nitramine)	68.5
TNB (trinitrobenzene)	65
Compound A ( $C_4H_6N_4O_7$ , formed by condensation of 1,1-dinitroethane)	77
Trinitroethyl trinitrobenzoate (27%)	80.5 (f)

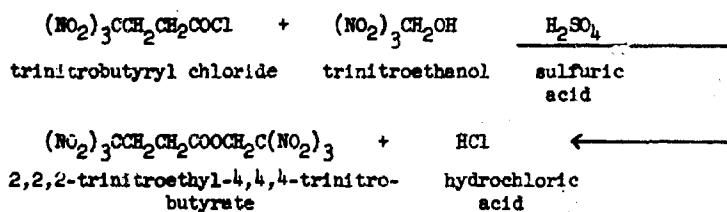
Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at  $89^{\circ}\text{C}$  giving Form II. Form II has a melting point of  $92.5^{\circ}$  to  $93^{\circ}\text{C}$ . On cooling, Form II does not transform reversibly to Form I when  $89^{\circ}\text{C}$  is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a very narrow temperature range on the order of  $0.2^{\circ}$  to  $0.5^{\circ}\text{C}$  near  $92.5^{\circ}\text{C}$ .

Preparation:

(d)



Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitroethanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid or fortified  $\text{H}_2\text{SO}_4$ , the ester can be prepared in yields of 95% to 98% in 24 hours at  $25^{\circ}\text{C}$ , in 5 hours at  $50^{\circ}\text{C}$ , or in 3 hours at  $65^{\circ}\text{C}$ . Above  $65^{\circ}\text{C}$  the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at  $92^{\circ}$  to  $93^{\circ}\text{C}$ .

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNTB)

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Origin:

(e)

TNTB belongs to a new class of explosives characterized by trinitromethyl groups,  $-C(NO_2)_3$ . The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Schimmelknecht, who discovered in 1942-1943 that trinitromethane or nitroform,  $HC(NO_2)_3$ , was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formaldehyde. Dr. Schimmelknecht reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the ester of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Navy began a program to explore these compounds. The initial task of investigating the chemistry of trinitroethanol was undertaken by the Hercules Powder Company (Navy Contract NOrd-9925). The U.S. Rubber Company studied the chemistry of nitroform (Navy Contract NOrd-10-129). After preparation of the first laboratory samples of TNTB, considerable interest was aroused. In early 1950 the Naugatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TNTB. The Bureau of Ordnance in July 1953 raised the production to 800 pounds with the assistance of the Hercules Powder Company in August. The production at Naugatuck (Navy Contract NOrd-11,280). TNTB is a high oxygen content explosive.

References: <sup>80</sup>

- (a) J. M. Rosen, Properties of Trinitroethyl Trinitrobutyrate TNTB, NAVORD Report No. 1750, 17 December 1950.
- (b) Bureau of Mines Report No. 3107, Part IX, Ballistic Mortar Tests on Trinitroethyl Trinitrobutyrate, 5 April 1950.
- (c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate as a Constituent of Castable Explosives, NAVORD Report No. 261, 30 September 1952.
- (d) U.S. Rubber Company Quarterly Progress Report No. 23, Synthesis of New Propellants and Explosives, Navy Contracts NOrd-10-129 and -12,663, 19 August 1953.
- (e) M. E. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of TNTB, a New Castable High Explosive, NAVORD Report No. 3885, 27 January 1955.
- (f) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965 1 April 1953.
- (g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, NAVORD Report No. 2997, 22 October 1953.
- (h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

<sup>80</sup>See footnote 1, page 10.

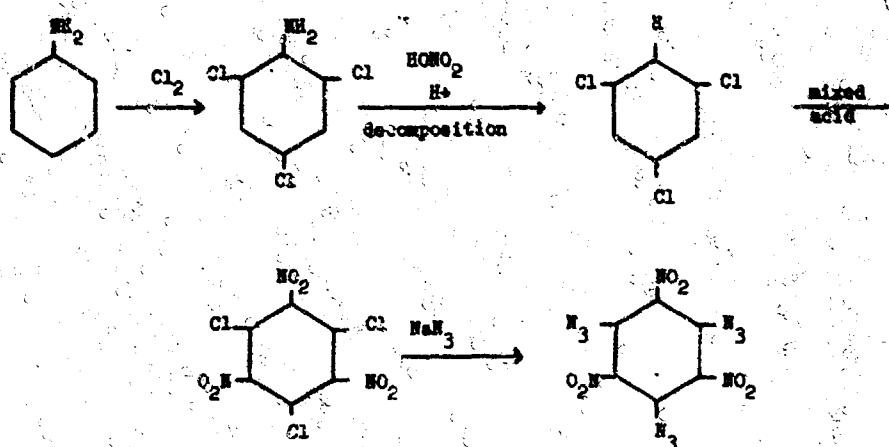
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Trinitro Triazidobenzene

<b>Composition:</b> %	<b>Molecular Weight:</b> $(C_6O_6N_{12})$ 336
C 22.4	Oxygen Balance: CO <sub>2</sub> % -29
N 50.0	CO % 0.0
O 28.6	<b>Density:</b> gm/cc <b>Crystal</b> 1.81
	<b>Melting Point:</b> °C <b>Decomposes</b> 131
<b>C/H Ratio</b>	<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm (a) 5.25	<b>Boiling Point:</b> °C
Sample Wt 20 mg	<b>Refractive Index:</b> n <sub>D<sup>20</sup></sub>
Picatinny Arsenal Apparatus, in.	n <sub>D<sup>25</sup></sub>
Sample Wt, mg	n <sub>D<sup>20</sup></sub>
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability Test:</b> cc/40 Hrs, at
<b>Rifle Bullet Impact Test:</b> Trials %	90°C 100°C 120°C 135°C 150°C
Explosions	<b>200 Gram Bomb Sand Test:</b> Sand, gm
Partials	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm
Burned	Mercury Fulminate Lead Azide Tetryl
Unaffected	<b>Ballistic Mortar, % TNT:</b>
<b>Exploded Temperature:</b> °C (a)	<b>Treitz Test, % PETN:</b> 90
Seconds, 0.1 (no cap used) --	<b>Plate Dent Test:</b> Method
1 --	Condition
5 150	Confined
10	Density, gm/cc
15	Brisance, % TNT
20	<b>Detonation Rate:</b> Confinement
<b>75°C International Heat Test:</b> % Loss in 48-Hrs	Condition
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs	Charge Diameter, in.
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Rate, meters/second
<b>Flammability Index:</b>	
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.00	
<b>Volatility:</b>	

Trinitro Triazidobenzene

<b>Fragmentation Test:</b>  90 mm HE, M21 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Gloss Cones Steel Cones Hole Volume Hole Depth	
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Color:</b> Greenish-yellow	
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb		<b>Principal Use:</b> (c) Ingredient of primer mix	
<b>Total No. of Fragments:</b> For TNT For Subject HE		<b>Method of Loading:</b> Pressed Dead presses at about 42,000 psi	
<b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc		<b>Loading Density:</b> gm/cc At 42,000 psi 1.75	
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy		<b>Storage:</b>  <b>Method:</b>	
<b>Air, Confined:</b> Impulse		<b>Hazard Class (Quantity-Distance):</b>	
<b>Under Water:</b> Peak Pressure Impulse Energy		<b>Compatibility Group:</b>	
<b>Underground:</b> Peak Pressure Impulse Energy		<b>Exudation:</b> None	
		<b>Qualitative Solubilities</b> at Room Temperature:	
		<b>Solvent</b> Solubility	
		Acetone Readily soluble	
		Chloroform Moderately soluble	
		Alcohol Sparingly soluble	
		Water Insoluble	
		<b>Compatibility with Metals:</b>	
		Wet: Does not attack iron, steel, copper or brass.	
		<b>Heat of:</b>	
		Combustion, cal/gm (a) 2554	
		<b>Burning Rate:</b> (b)	
		cm/sec 0.65	

Trinitro TriazidobenzenePreparation: (e)

Aniline is chlorinated to form trichloroaniline. The amino group is eliminated by the diazo reaction. The resulting  $\alpha$ -trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% oleum, adding strong nitric acid, and heating to 140°-150°C until no trinitro trichlorobenzene (melting point 187°C) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding an acetone solution of the trinitro trichlorobenzene, or better, and powdered substance alone, to an actively stirred solution of sodium azide in alcohol. The precipitated trinitro triazidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroform, allowing the solution to cool, and collecting the greenish yellow crystals (melting point 131°C with decomposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:<sup>81</sup>

- (a) S. Half, Tests of Explosive Compounds Submitted by Arthur D. Little, Inc., PATR 1750, 24 October 1949.
- (b) A. F. Belyaeva and A. E. Belyaeva CR a.s. USSR 52, 503-505 (1946) Chemical Abstracts 41, 4310.
- A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Nauk. USSR 56, 491-494 (1947).
- (c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).
- (d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).
- (e) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.
- (f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

<sup>81</sup>See footnote 1, page 10.

Tripenetaerythritol Octanitrate (TPEON)

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<b>Composition:</b> % C 24.6 H 3.3 N 15.3 O 56.6  CH <sub>2</sub> ONO <sub>2</sub> CH <sub>2</sub> ONO <sub>2</sub> CH <sub>2</sub> ONO <sub>2</sub>       O <sub>2</sub> NOCH <sub>2</sub> CONH <sub>2</sub> OCH <sub>2</sub> CONH <sub>2</sub> OCH <sub>2</sub> CONH <sub>2</sub>       CH <sub>2</sub> ONO <sub>2</sub> CH <sub>2</sub> ONO <sub>2</sub> CH <sub>2</sub> ONO <sub>2</sub> C/H Ratio 0.15	<b>Molecular Weight:</b> (C <sub>15</sub> H <sub>24</sub> N <sub>8</sub> O <sub>26</sub> ) 732
	<b>Oxygen Balance:</b> CO <sub>2</sub> % -35 CO % -2.2
	<b>Density:</b> gm/cc Crystal 1.58
	<b>Melting Point:</b> °C 82 to 84
	<b>Freezing Point:</b> °C
	<b>Boiling Point:</b> °C
<b>Impact Sensitivity, X Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg 9 Picatinny Arsenal Apparatus, in. Sample Wt, mg 24	<b>Refactive Index, n<sub>d</sub><sup>20</sup></b> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>20</sup> n <sub>d</sub> <sup>20</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C Pure 2.45 120°C Specially purified 1.94 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 58.9
<b>Explosion Temperatures:</b> °C Seconds, 0.1 (nc cap used) --- 1 --- 5 225 10 15 20	<b>Sensitivity to Initiation:</b> <b>Minimum Detonating Charge, gm</b> Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b>
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 1.15 % Loss, 2nd 48 Hrs 0.75 Explosion in 100 Hrs None	<b>Trexel Test, % TNT:</b>
<b>Flammability Index:</b>	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>Hygroscopicity:</b> %	<b>Detonation Rate:</b> Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.56 Rate, meters/second 7650
<b>Velocity:</b>	

Tripentaerythritol Octanitrate (TPEON)

<b>Booster Sensitivity Test:</b> Condition		<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec)
Tetryl, gm		
Wax, in. for 50% Detonation		Heat, kilocalories/mole (AH, kcal/mol) 23.1
Wax, gm		Temperature Range, °C 215 to 250
Density, gm/cc		Phase Liquid
<b>Heat of:</b> Combustion, cal/gm 2632		<b>Armor Plate Impact Test:</b>
Explosion, cal/gm 1085		60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec
Gas Volume, cc/gm 762		Aluminum Fineness
Formation, cal/gm		
Fusion, cal/gm		
<b>Specific Heat: cal/gm/°C</b>		<b>500-lb General Purpose Bombs:</b>
<b>Specific Impulse:</b> 1b-sec/lb (calculated) 240		Plate Thickness, inches
		1
		1½
		1½
		1¾
<b>Burning Rate:</b> cm/sec		<b>Bomb Drop Test:</b>
<b>Thermal Conductivity:</b> cal/sec/cm/°C		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
<b>Coefficient of Expansion:</b> Linear, %/°C		Max Safe Drop, ft
Volume, %/°C		500-lb General Purpose Bomb vs Concrete:
<b>Hardness, Mohs' Scale:</b>		Height, ft
<b>Young's Modulus:</b> E, dynes/cm <sup>2</sup>		Trials
E, lb/inch <sup>2</sup>		Unaffected
Density, gm/cc		Low Order
<b>Compressive Strength: lb/inch<sup>2</sup></b>		High Order
<b>Vapor Pressure:</b> °C mm Mercury		<b>1000-lb General Purpose Bomb vs Concrete:</b>
		Height, ft
		Trials
		Unaffected
		Low Order
		High Order

Tripentaerythritol Octanitrate (TPEON)

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<b>Fragmentation Test:</b>  90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth	
  3 inch HE, M42A1 Projectile, Lot KC-8: Density, gm/cc Charge Wt, lb  Total No. of Fragments: For TNT For Subject HE		  Color:                          White  <b>Principal Uses:</b> High explosive and as possible plasticizer for nitrocellulose	
  Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc		  <b>Method of Loading:</b> Cast or pressed  <b>Loading Density:</b> gm/cc Pressed at 60,000 psi                          1.565	
  <b>Blast (Relative to TNT):</b>  Air: Peak Pressure Impulse Energy		  <b>Storage:</b>  <b>Method:</b> Dry  <b>Hazard Class (Quantity-Distance):</b>  <b>Compatibility Group:</b>  <b>Exudation:</b> None	
  <b>Air, Confined:</b> Impulse		  <b>Hygroscopicity, Gain or Loss in Wt, %:</b>  <b>Time, Hrs</b> <u>  40  </u> <u>  70  </u> <u>  90  </u> % RH at 30°C  24                          -0.008      +0.01      +0.01 48                          -0.02      -0.01      +0.02 144                        -0.04      -0.03      -0.02 192                        -0.04      -0.02      ----- 216                        -0.004      -0.01      +0.03	
  <b>Under Water:</b> Peak Pressure Impulse Energy		  <b>Solubility:</b>  <b>Solvent</b> <u>Water</u> <u>Alcohol</u> <u>Chloroform</u> <u>Acetone, hot</u> <u>Benzene, hot</u> Solvent      Soluble      Soluble      Very soluble      Very soluble	
  <b>Underground:</b> Peak Pressure Impulse Energy			

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Tripentaerythritol Octanitrate (TPEON)Compatibility With Other High Explosives:100°C Vacuum Stability Test:

	NTN	PETN	RDX	TPEON
ml gas/40 hrs, 5 gm sample	0.14	2.15	0.39	2.45
ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HN	1.89	1.71	2.32	—

Dipentaerythritol Hexanitrate (DPERH)-TPEON Fusions:

% TPEON	% DPERH	Solidification Time, Days	MP, °C
100	0	—	83
95	5	3	68
90	10	3	69
80	20	5	73
50	50	30	60 (Eutectic)
20	80	5	63
10	90	3	69
0	100	—	73

Preparation:

(a)

Twenty grams (0.054 mol) of nitration grade tripentaerythritol (TPE) (99% minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litmus. The final product was washed successively with 50 cc each of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

Origin:

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10°C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

Tripentaerythritol Octanitrate (TPEON)

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References:<sup>82</sup>

- (a) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, The Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PATR No. 2490, 1958.
- (b) K. Mamba, J. Yamashita and S. Tanaka, "Pentaerythritol Tetranitrate," J Ind Explosives Soc (Japan) 15, 282-9 (1954); CA 49, 11283 (1955).
- (c) S. D. Brever and H. Henkin, The Stability of PETN and Pentolite, OSRD Report No. 1414.
- (d) E. Barlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

<sup>82</sup>See footnote 1, page 10.

<b>Composition:</b> %		<b>Molecular Weight:</b>	81
TNT	80	Oxygen Balance: CO <sub>2</sub> %	.77
Aluminum	20	CO %	.38
C/H Ratio		Density: gm/cc	Cast 1.72
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	85	Melting Point: °C	
Sample Wt 20 mg		Freezing Point: °C	
Picatinny Arsenal Apparatus, in.	13	Boiling Point: °C	
Sample Wt, mg	16	Refractive Index, n <sub>d20</sub>	n <sub>d20</sub> n <sub>d20</sub> n <sub>d20</sub>
Friction Pendulum Test:		Vacuum Stability Test: cc/40 Hrs, at 90°C	
Steel Shoe	Unaffected	100°C	0.1
Fiber Shoe	Unaffected	120°C	0.2
Rifle Bullet Impact Test: Trials	%	135°C	--
Explosions	60	150°C	0.8
Partials	0	200 Gram Bomb Sand Test: Sand, gm	
Burned	0	Sensitivity to Initiation: Minimum Detonating Charge, gm	
Unaffected	40	Mercury Fulminate	
Explosion Temperature: °C		Lead Azide	0.20
Seconds, 0.1 (no cap used)	610	Tetryl	0.10
1	520	Ballistic Meter, % TNT: (a)	124
5 Decomposes	470	Trotzel Test, % TNT: (b)	125
10	465	Plate Dent Test: (c)	
15		Method	B
20		Condition	Cast
75°C International Heat Test: % Loss in 48 Hrs		Confined	No
100°C Heat Test: % Loss, 1st 48 Hrs		Density, gm/cc	1.75
% Loss, 2nd 48 Hrs		Brisance, % TNT	93
Explosion in 100 Hrs		Decomposition Rate: Confinement	None
Flammability Index:	100	Condition	Cast
Hygroscopicity: % 30°C, 90% RH	0.00	Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.71
		Rate, meters/second	6475
			6700

<b>Buster Sensitivity Test:</b> (d)		Cast	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec) Heat, kilocalories/mole (ΔH, kcal/mol) Temperature Range, °C Phase		
Condition			Tetryl, gm	100	
Wax, in. for 50% Detonation	0.58		Wax, gm		
Density, gm/cc	1.75				
<b>Heat of:</b> (c)			<b>Armor Plate Impact Test:</b> (e)		
Combustion, cal/gm	4480		60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec	509 >1100	
Explosion, cal/gm	1770		Aluminum Fineness	100 12	
Gas Volume, cc/gm					
Formation, cal/gm					
Fusion, cal/gm					
<b>Specific Heat:</b> cal/gm/°C (b)			<b>500-lb General Purpose Bombs:</b>		
At -5°C	0.23		Plate Thickness, inches	<u>Trials</u> <u>% Inert</u>	
Density, gm/cc	1.74		1	0	
At 20°C	0.31		1 1/4	6 100	
			1 1/2	6 33	
			1 3/4	0	
<b>Burning Rate:</b> cm/sec			<b>Bomb Drop Test:</b> (e)		
<b>Thermal Conductivity:</b> cal/sec/cm/°C (b)			<b>T7, 2000-lb Semi-Arm.-Piercing Bomb vs Concrete:</b>		
11 x 10 <sup>-4</sup>			Max Safe Drop, ft		
Density, gm/cc	1.73		<b>500-lb General Purpose Bomb vs Concrete:</b>		
			Height, ft	<u>Seal</u> <u>Seal</u>	
<b>Coefficient of Expansion:</b> Linear, %/°C			4,000	5,000	
Volume, %/°C			Trials	34 14	
<b>Hardness, Mohs' Scale:</b>			Unaffected	32 14	
<b>Young's Modulus:</b> (b)			Low Order	0 0	
E', dynes/cm <sup>2</sup>	6.67 x 10 <sup>10</sup>		High Order	2 0	
E, lb/inch <sup>2</sup>	0.97 x 10 <sup>6</sup>		<b>1000-lb General Purpose Bomb vs Concrete:</b>		
Density, gm/cc	1.72		Height, ft	<u>Seal</u> 5,000	
<b>Compressive Strength:</b> lb/inch <sup>2</sup> (b)			Trials	24	
Density, gm/cc	2340		Unaffected	23	
Vapor Pressure:	mm Mercury		Low Order	0	
°C			High Order	1	

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	1.71	Hole Volume	
Charge Wt, lb	2.272	Hole Depth	
Total No. of Fragments:		Color:	Gray
For TNT	703	Principal Uses:	GP bombs
For Subject HE	616	Method of Loading:	Cast
8 inch HE, M42A1 Projectile, Lot KC-5:		Loading Density: gm/cc	1.65-1.72
Density, gm/cc	1.75	Storage:	
Charge Wt, lb	0.914	Method	Dry
Total No. of Fragments:		Hazard Class (Quantity-Distance)	Class 9
For TNT	514	Compatibility Group	Group I
For Subject HE	485	Exudation	
Fragment Velocity: ft/sec		Preparation:	
At 9 ft	2460	Tritonal is prepared by adding TNT and aluminum separately to a steam-jacketed melt kettle equipped with a stirrer. Heating of the kettle and mixing of the ingredients are continued until all the TNT is melted. When the viscosity of the mixture is considered satisfactory (about 85°C), the tritonal is poured into projectiles or bombs the same as TNT.	
At 25½ ft	2380		
Density, gm/cc	1.72		
Blow (Relative to TNT): (r)			
Air:			
Peak Pressure	110		
Impulse	115		
Energy	119		
Air, Confined:			
Impulse	130		
Under Water:			
Peak Pressure	105		
Impulse	118		
Energy	119		
Underground:			
Peak Pressure	117		
Impulse	127		
Energy	136		

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TNT/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decreased by additions of aluminum up to 40% (Ref j). For all practical purposes it is concluded that the addition of 18% to 20% aluminum to TNT improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TNT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TNT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:<sup>83</sup>

- (a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Div 2 and 8, NDRC, Report on HEY and Tritonal, OSRD No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) W. B. Kennedy, R. F. Arentzen and C. W. Tait, Survey of the Performance of TNT/Al on the Basis of Air-Blast Pressure and Impulse, OSRD Report No. 4549, Division 2, Monthly Report No. AEB-6, 25 January 1945.
- (h) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1290, First Progress Report, 19 May 1943.
- (i) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PATR No. 1380, Second Progress Report, 12 January 1944.
- (j) L. S. Wise, Effect of Aluminum on the Rate of Detonation of TNT, PATR No. 1550, 26 July 1945.
- (k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

<sup>83</sup>See footnote 1, page 10.

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Tritonal, 80/20

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

<u>0</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1530	1693	1444	1635	1956	1737	2138
1560	2353				2127	
2010						

<b>Composition:</b>		<b>Molecular Weight:</b>	281
% HMX	70.0	Oxygen Balance:	
Nitroncellulose (13.15% N)	15.0	CO, %	-26
Nitroglycerin	10.7	CO %	-0.5
2-Nitrodiphenylamine	1.3	<b>Density: gm/cc</b>	Pressed 1.72
Triacetin	3.0	<b>Melting Point: °C</b>	
<b>C/H Ratio</b>		<b>Freezing Point: °C</b>	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point: °C</b>	
Bureau of Mines Apparatus, cm		Refractive Index, $n_{D}^{20}$	
Sample Wt 20 mg		$n_{D}^{20}$	
Picatinny Arsenal Apparatus, in.		$n_{D}^{20}$	
Sample Wt, mg		$n_{D}^{20}$	
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
<b>Rifle Bullet Impact Test:</b>	Trials	100°C	1.20
	%	120°C 29 hours	11+
Explosions		135°C	
Partials		150°C	
Burned		<b>200 Gram Bomb Sand Test:</b>	
Unaffected		Sand, gm	66.4
<b>Explosion Temperature:</b> °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (in cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	----
5		Lead Azide	0.30
10		Tetryl	----
15		<b>Ballistic Mortar, % TNT:</b>	
20		<b>Trend Test, % TNT:</b>	
<b>75°C International Heat Test:</b>		<b>Plate Dent Test:</b>	
% Loss in 48 Hrs		Method	
<b>90°C Heat Test:</b>		Condition	
% Loss, 1st 48 Hrs	0.28	Confined	
% Loss, 2nd 48 Hrs	1.12	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
<b>Flammability Index:</b>		<b>Detonation Rate:</b>	
<b>Hygroscopicity:</b> %		Confinement	
<b>Volatility:</b>		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second (calculated)	8500

\*See footnote on following page.

<b>Booster Sensitivity Test:</b>	<b>Decomposition Equation:</b>				
Condition	Oxygen, atoms/sec (Z/sec)				
Tetryl, gm	Heat, kilocalorie/mole (ΔH, kcal/mol)				
Wax, in. for 50% Detonation	Temperature Range, °C				
Wax, gm	Phase				
Density, gm/cc					
<b>Heat of:</b>	<b>Armor Plate Impact Test:</b>				
Combustion, cal/gm	2359				
Explosion, cal/gm	1226				
Gas Volume, cc/gm					
Formation, cal/gm					
Fusion, cal/gm					
<b>Compression at Rupture: %</b>	8.26				
<b>Work to Produce Rupture:</b>					
ft-lb/inch <sup>3</sup>	9.62				
<b>Burning Rate:</b>					
cm/sec					
<b>Thermal Conductivity:</b>					
cal/sec/cm/°C					
<b>Coefficient of Expansion:</b>					
Linear, %/°C					
<b>Volume, %/°C</b>					
<b>Hardness, Mohs' Scale:</b>					
<b>Young's Modulus:</b>					
E', dynes/cm <sup>2</sup>	0.24 × 10 <sup>10</sup>				
E, lb/inch <sup>2</sup>	0.35 × 10 <sup>5</sup>				
Density, gm/cc					
<b>Compressive Strength: lb/inch<sup>2</sup></b>	2720				
<b>Vapor Pressure:</b>					
°C	mm Mercury				
*Name assigned by Dr. Mar. M. Jones, formerly of PA; based on original development by James H. Veltman.					
<b>500-lb General Purpose Bomb:</b>					
Plate Thickness, inches					
1					
1½					
1¾					
<b>Bomb Drop Test:</b>					
T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:					
Max Safe Drop, ft					
<b>500-lb General Purpose Bomb vs Concrete:</b>					
Height, ft					
Trials					
Unaffected					
Low Order					
High Order					
<b>1000-lb General Purpose Bomb vs Concrete:</b>					
Height, ft					
Trials					
Unaffected					
Low Order					
High Order					

<b>Fragmentation Test:</b> 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Shaped Charge Effectiveness, TNT = 100:</b> Glass Cones      Steel Cones Hole Volume Hole Depth	
	Color:	Orange
	Principal Uses:	High mechanical strength machinable explosive
	Method of Loading:	Pressed
	Loading Density: gm/cc At 6,700 psi	1.72
	Storage:	Dry
	Hazard Class (Quantity-Distance)	
	Compatibility Group	
	Exudation	None
	Machinability	Excellent

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agitator. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Raise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The HMX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture content between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished collar is then preheated on a heat table at 65°C. Increments of 25 gm each are pressed at 670 psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determine the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloidizing agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference:<sup>84</sup>

(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

<sup>84</sup>See footnote 1, page 10.

AMCP 706-177

(AMCRD-TV)

FOR THE COMMANDER:

OFFICIAL:

*P. R. Horne*  
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Colonel, GS  
Chief, HQ Admin Mgt Ofc

CHARLES T. HORNER, JR.  
Major General, USA  
Chief of Staff

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