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ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES

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. Sheffield, 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 with 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:

Commanding General
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:

Commanding General
U. S. Army Materiel Command
ATTN: AMCRD-TV
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.

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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	Aberdeen Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-NEC	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 société 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 séances de l'Académie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des séances de l'Académie 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 ² .
E'	same as E, but expressed in dynes/cm ² .
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 Ind Explosives Soc	Journal of the Industrial Explosives Society (Japan).
J prakt Chem	Journal für praktische Chemie.
LA	lead azide
Land-Bornst	Landolt-Bornstein Physikalisch-Chemische Tabellen, 5th Edition (Berlin).
M	molar.
N	Monatshefte für Chemie (Wein).
Mém poudr	Mémorial des poudres et salpêtres (Paris).
mg	milligram.

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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.
NOL	U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.
NOTS	U. S. Naval Ordnance Test Station, China Lake, Calif.
NRC	National Research Council.
OB	oxygen balance.
OCM	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	Poggendorff'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.
sol	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.

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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 "Uniterm 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 EM 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 EM 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 PA 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 EM 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.

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(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 a 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 mw₁, mw₂, mw₃ and mw_n 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 gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

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

\div molecular weight of compound = oxygen balance to CO_2 and H_2O , where X = 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:

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

(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

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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 1 (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 boosted 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.

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

(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 Bruceton 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 Acrafax 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

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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 ± 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, n)

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 charges 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. M9A1 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 Materiel 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/TO 11A-1-34).

(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) Exudation.

d. 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-weighted 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)

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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.

5. REFERENCES CITED IN INTRODUCTION.¹

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/TO 11A-1-34, Military Explosives, April 1955.

e. J. H. McIvor, Ballistic Mortar Test, PA Testing Manual 7-2, 8 May 1950.

f. Ph. Naum, Zug-Schleiss-Sprengstoff, 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.

¹For 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, NDRC Contract W-672-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, NDRC Contract W-672-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. 3852, 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. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD 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. 1524, 1 September 1950.

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

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Amatol, 80/20

Composition: % Ammonium Nitrate 80 TNT 20 C/H Ratio	Molecular Weight: 92	
	Oxygen Balance: CO ₂ % +1 CO % +11	
	Density: gm/cc	Cast 1.46
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.45 120°C 0.95 135°C 150°C 6.8	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 35.5	
Rifle Bullet Impact Test: 5 Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.07	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20	Ballistic Mortar, % TNT: (a) 130	
	Trauzl Test, % TNT: (b) 123	
75°C International Heat Test: % Loss in 48 Hrs 0.06	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Detonation Rate: Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.46 1.46 Rate, meters/second 4500 5100	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH, 2 days 61		
Volatility: Nil		

Amatol, 80/20

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec (f) At 9 ft 1900 At 25½ ft 1750 Density, gm/cc	Color: Buff-yellow
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Bombs, HE projectiles
	Method of Loading: Cast
	Loading Density: gm/cc 1.46
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C
	Booster Sensitivity Test: (a) <div> Condition Pressed </div> Tetryl, gm 100 Wax, in. for 50% Detonation 0.83 Density, gm/cc 1.65 Heat of: (d, e) <div> Combustion, cal/gm 1002* </div> <div> Explosion, cal/gm 490* </div> <div> Gas Volume, cc/gm 930* </div> *Calculated from composition of mixture.

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Amatol, 60/40

Composition: %		Molecular Weight: 108	
Ammonium Nitrate 60		Oxygen Balance:	
TNT 40		CO ₂ % -18	
		CO % + 2	
		Density: gm/cc	Cast 1.60
		Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm 95		Refractive Index, n_D²⁰	
Sample Wt 20 mg		n _D ²⁰	
Picatinny Arsenal Apparatus, in. 16		n _D ²⁵	
Sample Wt, mg 17			
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
		100°C	
		120°C	
		135°C	
		150°C	
Rifle Bullet Impact Test: Trials		200 Gram Bomb Sand Test:	
% %		Sand, gm 41.5	
Explosions		Sensitivity to Initiation:	
Partials		Minimum Detonating Charge, gm	
Burned		Mercury Fulminate	
Unaffected		Lead Azide 0.20	
		Tetryl 0.06	
Explosion Temperature: °C		Ballistic Meter, % TNT: (a) 128	
Seconds, 0.1 (no cap used)		Trouzi Test, % TNT:	
1		Plate Dent Test:	
5 Decomposes 270		Method	
10		Condition	
15		Confined	
20		Density, gm/cc	
		Brisance, % TNT	
75°C International Heat Test:		Detonation Rate:	
% Loss in 48 Hrs		Confinement None	
		Condition Cast	
100°C Heat Test:		Charge Diameter, in. 1.0	
% Loss, 1st 48 Hrs		Density, gm/cc 1.50	
% Loss, 2nd 48 Hrs		Rate, meters/second 5760	
Explosion in 100 Hrs			
Flammability Index:			
Hygroscopicity: %			
Volatility: Nil			

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Amatol, 50/50

Composition: % Ammonium Nitrate 50 TNT 50 C/H Ratio	Molecular Weight: 118	
	Oxygen Balance: CO, % -27 CO %, - 3	
	Density: gm/cc	Cast 1.59
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Vt, mg 17	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{20} n_D^{20}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 1.0 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions 0 Partials 0 Burned 0 Unaffected 100	200 Gram Bomb Snd Test: Snd, gm 42.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.05	
	Ballistic Marker, % TNT: (a) 124	
	Treuzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method B Condition Cast Confined No Density, gm/cc 1.55 Brisance, % TNT 52	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: 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	
Flammability Index:		
Hygroscopicity: %	Nil	
Volatility:		

Amatol, 50/50

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.55 Charge Wt, lb 2.053 Total No. of Fragments: For TNT 703 For Subject HE 630 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.54 Charge Wt, lb 0.819 Total No. of Fragments: For TNT 514 For Subject HE 385	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (g) Hole Volume 53 Hole Depth 69 Color: Buff-yellow Principal Uses: Bombs, HE projectiles Method of Loading: Cast Loading Density: gm/cc 1.59
Fragment Velocity: ft/sec At 9 ft At 25 1/3 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C
Blast (Relative to TNT): Air: Peak Pressure 97 Impulse 87 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy 98 Underground: Peak Pressure 104 Impulse 104 Energy 104	Booster Sensitivity Test: (a) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.60 Density, gm/cc 1.55 Heat of: (d, e) Combustion, cal/gm 1990 Explosion, cal/gm 703* Gas Volume, cc/gm 855* *Calculated from composition of mixture. Specific Heat: cal/gm/°C (i) Temp, 20° to 80°C 0.383 Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 4000-5000

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Amatols 80/20, 60/40, 50/50Compatibility 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. Continue 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:²

(a) L. C. Smith and E. H. Eyster, 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. McDougall, 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.

(d) Committee of Div 2 and 8, NDRC, Report on HBX 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:

<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>
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	734	695	666	1797	838	920
950	1051	1352	1323	874	715	986	1827	1098	1129
1300	1311	1372	1493	1344	735	1376	2167	1148	1219
1530	1451	1552	1783		1145	1446		1388	1369
	1651				1225	1636		1568	1559
					1345	1796		1838	
					1455				
					1885				

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

²See footnote 1, page 10.

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Composition: % Ammonium Nitrate 22 TNT 67 Aluminum 11 C/H Ratio	Molecular Weight: 102	
	Oxygen Balance: C, % -55 CO % -22	
	Density: gm/cc	Cast 1.65
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 91 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_{20}^D n_{20}^D n_{20}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 4.4 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 47.8	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20 Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a) 122	
75°C International Heat Test: % Loss in 48 Hrs	Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

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Ammonal

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, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.65 Charge Wt, lb Total No. of Fragments: For TNT 655 For Subject HE 550	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Projectile filler Method of Loading: Cast Loading Density: gm/cc 1.65
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Preparation: 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.	Origin: Castable mixture developed in United States during World War I. References: (a) W. R. Tomlinson, Jr., <u>Physical and Explosive Properties of Military Explosives</u> , PATR No. 1372, 29 November 1943. (b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.

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Comp. solution: %			Molecular Weight: ($\text{H}_4\text{N}_2\text{O}_3$) 80	
N	35		Oxygen Balance:	
H	5	NH_4NO_3	CO_2 %	+20
O	60		CO %	+20
C/4 Ratio			Density: gm/cc	Crystal 1.73
			Melting Point: °C	170
			Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C	
Bureau of Mines Apparatus, cm 100+			Refractive Index, n_D^{20}	
Sample Wt 20 mg			n_D^{20}	
Picatinny Arsenal Apparatus, in. 31			n_D^{20}	
Sample Wt, mg 17				
Friction Pendulum Test:			Vacuum Stability Test:	
Steel Shoe Unaffected			cc/40 Hrs, at	
Fiber Shoe Unaffected			90°C	
			100°C 0.3	
			120°C 0.3	
			135°C	
			150°C 0.3	
Rifle Bullet Impact Test: Trials			200 Gram Bomb Seed Test:	
Explosions %			Sand, gm	
Portals 0			M11	
Burned 0				
Unaffected 100				
Explosion Temperature: °C			Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)			Minimum Detonating Charge, gm	
1			Mercury Fulminate	
5 Ignites 465			Lead Azide 0.20	
10			Tetryl 0.25	
15				
20				
75°C International Heat Test: (a)			Ballistic Mortar, % TNT: (a) 56	
% Loss in 48 Hrs 0.0			Treuzl Test, % TNT:	
100°C Heat Test:			Plate Dent Test:	
% Loss, 1st 48 Hrs 0.74			Method	
% Loss, 2nd 48 Hrs 0.13			Condition	
Explosion in 100 Hrs None			Confined	
			Density, gm/cc	
			Brisance, % TNT	
Flammability Index:			Detonation Rate: (b)	
			Confinement None Strong	
			Condition Solid Liquid	
			Charge Diameter, in. 1.25 4.5	
			Density, gm/cc 0.9 1.4	
			Rate, meters/second 1000 2500	
Hygroscopicity: %				
30°C, 90% RH Extreme				
Volatility:				
Decomposes at 210°C				

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Ammonium Nitrate

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: (i) (h) Oxygen, atoms/sec $10^{13.8}$ $10^{12.3}$ (Z/sec) Heat, kilocalorie/mole 40.5 38.3 (ΔH , kcal/mol) Temperature Range, °C 243-261 217-267 Phase Liquid																
Heat of: Combustion, cal/gm 346 Explosion, cal/gm 346 Gas Volume, cc/gm 980 Formation, cal/gm 1098 Fusion, cal/gm 18.23	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4																
Specific Heat: cal/gm/°C (e) <table><tr><th>°C</th><th></th><th>°C</th><th></th></tr><tr><td>-150</td><td>0.189</td><td>0</td><td>0.397</td></tr><tr><td>-100</td><td>0.330</td><td>50</td><td>0.414</td></tr><tr><td>-50</td><td>0.364</td><td>100</td><td>0.428</td></tr></table>	°C		°C		-150	0.189	0	0.397	-100	0.330	50	0.414	-50	0.364	100	0.428	Bomb Drop Test: 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
°C		°C															
-150	0.189	0	0.397														
-100	0.330	50	0.414														
-50	0.364	100	0.428														
Burning Rate: cm/sec																	
Thermal Conductivity: cal/sec/cm/°C $2.9-3.9 \times 10^{-4}$																	
Coefficient of Expansion: Linear, %/°C Volume, %/°C																	
Hardness, Mohs' Scale:																	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc																	
Compressive Strength: lb/inch²																	
Vapor Pressure: (g) °C mm Mercury 188 3.25 205 7.45 216 11.55 223 15.80 237 27.0 240 41.0																	

Ammonium Nitrate

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> 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												
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 12 Compatibility Group Group D Exudation None												
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b) <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Temp. °C</th><th style="text-align: left;">PA Impact Test 2 Kg Wt, inches</th></tr> </thead> <tbody> <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> Compatibility with Metals: (a) In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium. Entropy: (g) <div style="display: flex; justify-content: space-between;"> cal/mol at 25°C 36.0 </div>	Temp. °C	PA Impact Test 2 Kg Wt, inches	25	31	75	28	100	27	150	27	175	12
Temp. °C	PA Impact Test 2 Kg Wt, inches												
25	31												
75	28												
100	27												
150	27												
175	12												

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Ammonium Nitrate

Solubility 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>
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>% Nitric Acid</u>
0	113	20	2.5	16.6	0.0	0	45.1	30.0
20	192	40	5	27.0	0.39	15	73.0	21.7
40	297	60	7.5	80.9	5.8	30	106	20.8
60	421	78	10.5	101.0	20.7	75	201	31.6
80	580			120.0	125			
100	871							

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 alkalis with the liberation of ammonia, and by sulfuric acid with the formation of ammonium sulfate and nitric acid.

References:³

- (a) Departments of the Army and the Air Force TM 9-1910/TO 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. 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) 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.

³See footnote 1, page 10.

Ammonium Nitrate

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

<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>
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	1051	1682	1783	1094	1225	676	1947	938	1409
1290	1241		2183	1214	1455	946	2167	1008	
1720	1311			1234	1635	1106		1038	
	1391			1304	1675	1696			
	1431				1725				

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Ammonium Perchlorate

Composition: % Cl 30.2 N 11.9 H 3.4 O 54.5 C/H Ratio NH ₄ ClO ₄	Molecular Weight: (ClH ₄ NO ₄) 117.5	
	Oxygen Balance: CO ₂ % +27.3 CO % +27.3	
	Density: gm/cc 1.95	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 67 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 24 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n_D n _D n _D	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.13 120°C 0.20 135°C 150°C 0.32	
Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe Unaffected	200 Gram Bomb Sens. Test: Sand, gm 6.0	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25	
	Ballistic Mortar, % TNT:	
	Treuzl Test, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 435 10 15 20	Plate Dent Test: Method Condition Confined Density, gm/cc Brisonce, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.02 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Ammonium Perchlorate

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Colorless Principal Uses: Explosive ingredient of mixtures used in pyrotechnics and as projectile filler Method of Loading: Pressed or cast depending on composition of mixture Loading Density: gm/cc Variable
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility in Water <u>gm/100 cc saturated solution:</u> <div> 0°C 12 25°C 20 60°C 39 100°C 88 </div> Preparation: 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). Heat of: Formation, cal/gm 665

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Ammonium PerchlorateOrigin: (c)

E. Mitscherlich first prepared, in 1832, crystals of ammonium perchlorate from barium perchlorate and ammonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of sodium perchlorate with ammonium chloride, and on cooling, crystals of ammonium perchlorate were obtained (Comp rend, 73, 1269, [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, 1898). A. Miolati 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:⁴

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR 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. 396.

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

⁴See footnote 1, page 10.

Baratol

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Composition: % Barium nitrate 67 TNT 33 C/H Ratio	Molecular Weight: 125	
	Oxygen Balance: CO ₂ % -3 CO % +13	
	Density: gm/cc	Cast 2.55
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 24	Boiling Point: °C	
	Refractive Index, n_D	
	n _D n _D	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 26.8	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 38.5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: (a) 73/27 Method B Condition Cast Confined No Density, gm/cc 2.52 Brisance, % TNT 61	
Flammability Index:	Detonation Rate:	
Hygroscopicity: % 30°C, 90% RH 0.00	Confinement	
	Condition	
Volatility:	Charge Diameter, in.	
	Density, gm/cc	
	Rate, meters/second	

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Baratol

Booster Sensitivity Test: Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.32 Wax, gm Density, gm/cc 2.55		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase																					
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm 75/25 Baratol 2.8 (d)		Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4																					
Specific Heat: cal/gm/°C (d) 75/25 Baratol <table> <tr> <th>°C</th><th></th><th>°C</th><th></th></tr> <tr> <td>-75</td><td>0.152</td><td>75</td><td>0.280</td></tr> <tr> <td>0</td><td>0.147</td><td>85</td><td>0.213</td></tr> <tr> <td>25</td><td>0.180</td><td>90</td><td>0.201</td></tr> <tr> <td>50</td><td>0.229</td><td>100</td><td>0.171</td></tr> </table>		°C		°C		-75	0.152	75	0.280	0	0.147	85	0.213	25	0.180	90	0.201	50	0.229	100	0.171	Bomb Drop Test: 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	
°C		°C																					
-75	0.152	75	0.280																				
0	0.147	85	0.213																				
25	0.180	90	0.201																				
50	0.229	100	0.171																				
Burning Rate: cm/sec																							
Thermal Conductivity: cal/sec/cm/°C																							
Coefficient of Expansion: Linear, %/°C Volume, %/°C																							
Hardness, Mohr Scale:																							
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc																							
Compressive Strength: lb/inch²																							
Vapor Pressure: °C mm Mercury																							

Baratol

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Principal Uses: Bomb filler Method of Loading: Cart Loading Density: gm/cc 2.55									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <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> Preparation: 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. Origin: Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation		
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation										

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BaratolReferences:⁵

- (a) D. P. MacDougall, Methods of Physical Testing, USRD Report No. 803, 11 August 1942.
- (b) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OQRD 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.

⁵See footnote 1, page 10.

Baronal

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Composition: % Barium nitrate 50 TNT 35 Aluminum 15 C/H Ratio	Molecular Weight: 111	
	Oxygen Balance: CO ₂ % -24 CO % -7	
	Density: gm/cc 2.32	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
	Friction Pendulum Test: Steel Shoe Fiber Shoe	
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	
	200 Gram Bomb Sand Test: Sand, gm 39.8	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 345 10 15 20	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 96	
	Treuzl Test, % TNT:	
Flammability Index: Hygroscopicity: % Volatility:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: (b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 2.32 Rate, meters/second 5450	

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Baronal

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: center;">Glass Cones Steel Cones</div> Hole Volume Hole Depth																
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Bomb filler																
	Method of Loading: Cast																
	Loading Density: gm/cc 232																
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation																
	Preparation: Procedure same as described under Barotol except aluminum is added to the barium nitrate-TNT molton mixture under agitation until uniformity in comparison is obtained. Booster Sensitivity Test: <table border="0" style="width: 100%;"> <tr> <td>Condition</td> <td style="text-align: right;">(c)</td> </tr> <tr> <td>Tetryl, gm</td> <td style="text-align: right;">Cast</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td style="text-align: right;">100</td> </tr> <tr> <td>Density, gm/cc</td> <td style="text-align: right;">0.86</td> </tr> <tr> <td></td> <td style="text-align: right;">2.32</td> </tr> </table> Heat of: <table border="0" style="width: 100%;"> <tr> <td>Combustion, cal/gm</td> <td style="text-align: right;">2099</td> </tr> <tr> <td>Explosion, cal/gm</td> <td style="text-align: right;">1135</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td style="text-align: right;">410</td> </tr> </table>	Condition	(c)	Tetryl, gm	Cast	Wax, in. for 50% Detonation	100	Density, gm/cc	0.86		2.32	Combustion, cal/gm	2099	Explosion, cal/gm	1135	Gas Volume, cc/gm	410
Condition	(c)																
Tetryl, gm	Cast																
Wax, in. for 50% Detonation	100																
Density, gm/cc	0.86																
	2.32																
Combustion, cal/gm	2099																
Explosion, cal/gm	1135																
Gas Volume, cc/gm	410																

Baronal

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References:⁶

- (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) 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.
- (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. 2138, February 1955.

⁶See footnote 1, page 10.

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Black Powder

Composition: % Potassium nitrate 74.0 Sulfur 10.4 Charcoal 15.6 C/H Ratio	Molecular Weight: 84	
	Oxygen Balance: CO ₂ % -22 CO % -2	
	Density: gm/cc Variable	
	Melting Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 16	Freezing Point: °C	
	Boiling Point: °C	
	Refractive Index, $n_{D_{20}}^0$ $n_{D_{25}}^0$ $n_{D_{30}}^0$	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.5 120°C 0.9 135°C 150°C	
Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 8	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Sensitive to igniting fuse	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 510 1 490 5 Ignites 427 10 356 15 20	Ballistic Mortar, % TNT: 50 Treuzl Test, % TNT: (a) 10	
75°C International Heat Test: % Loss in 48 Hrs 0.31	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.6 Rate, meters/second 400	
Flammability Index:		
Hygroscopicity: % 25°C, 75% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51		
Volatility:		

Black Powder

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Black Principal Uses: 1. Igniter powder 2. Time rings (fuzes) Method of Loading: 1. Loose (granulated) 2. Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc psi x 10³ <div style="display: flex; justify-content: space-around;"> 255060657075 </div> <div style="display: flex; justify-content: space-around;"> 1.741.841.861.871.881.89 </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Initiating Efficiency:</u> <u>Grams Required to Initiate</u> <div style="display: flex; justify-content: space-between;"> Igniter Comp K-31 2.0 </div> <div style="display: flex; justify-content: space-between;"> Igniter Comp K-29 2.3 </div>	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group 0 Exudation None <u>100°C Vacuum Stability Test,</u> <u>cc gas/40 hrs:</u> Initial Value 0.5 After 2 hours at 65°C 0.86 After 2 hours at 65°C, 75% RH 1.46 <u>Sensitivity to Electrostatic</u> <u>Discharge, Joules:</u> (b) Unconfined >12.5 Confined 0.8 <u>Compatibility with Metals:</u> Dry - Compatible with all metals when moisture content is less than 0.20%. Wet - Attacks all common metals except stainless steel. <u>Heat of:</u> <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm 684 </div> <div style="display: flex; justify-content: space-between;"> Gas Volume, cc/gm 271 </div>

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Black PowderPreparation:

Willow or alder charcoal, flour or 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:⁷

- (a) Ph. Naum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.
- (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:

⁷See footnote 1, page 10.

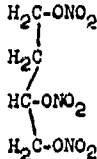
Black Powder

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<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	91	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 (BITN) Liquid

Composition:			Molecular Weight: (C ₄ H ₇ N ₃ O ₉)			241
%			Oxygen Balance:			
C	19.9		CO ₂ %			-17
H	2.9		CO %			10
N	17.5					
O	59.7					
C/H Ratio	0.13					
Impact Sensitivity, 2 Kg Wt:						
Bureau of Mines Apparatus, cm						58
Sample Wt 20 mg						
Picatinny Arsenal Apparatus, in.						NA 1
Sample Wt, mg						
Friction Pendulum Test:						
Steel Shoe						
Fiber Shoe						
Rifle Bullet Impact Test:			Trials			
			%			
Explosions						
Partials						
Burned.						
Unaffected						
Explosion Temperature:			°C			
Seconds, 0.1 (no cap used)						
1						
5 Decomposes			230			
10						
15						
20						
75°C International Heat Test:						
% Loss in 48 Hrs						
100°C Heat Test:						
% Loss, 1st 48 Hrs			1.5			
% Loss, 2nd 48 Hrs			1.2			
Explosion in 100 Hrs			None			
Flammability Index:						
Hygroscopicity: % (μ)						
100°F, 95% RH, 24 hrs			0.14			
Volatility:						
60°C, mg/cm ² /hr			46			
Boiling Point: °C						
Refractive Index, n_D²⁰			1.4738			
n_D²⁵						
n_D³⁰						
Vacuum Stability Test:						
cc/40 Hrs, at						
90°C						
100°C			2.33			
120°C						
135°C						
150°C						
200 Gram Bomb Sand Test:						
Sand, gm			48.6			
Sensitivity to Initiation:						
Minimum Detonating Charge, gm						
Mercury Fulminate						
Lead Azide			0.20			
Tetryl			0.10			
Ballistic Mortar, % TNT:						
Treuzl Test, % TNT:						
Plate Dent Test:						
Method						
Condition						
Confined						
Density, gm/cc						
Brisance, % TNT						
Detonation Rate:						
Confinement						
Condition						
Charge Diameter, in.						
Density, gm/cc						
Rate, meters/second						

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

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow oil Principal Uses: Explosive plasticizer for nitrocellulose Method of Loading:
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 1.72 Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Heat of: (a) Combustion, cal/gm 2168 Explosion, cal/gm 1457 Gas Volume, cc/gm 840	Solubility in Water, (a) <u>gm/100 gm, at:</u> 20°C 0.08 60°C 0.15 Solubility of Water in, (a) <u>gm/100 gm:</u> 0.04 Solubility, gm/100 gm, <u>at 25°C, in:</u> Ether - Alcohol - 2:1 Ether:Alcohol - Acetone - Viscosity, centipoises: (a) Temp. 25°C 59

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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:⁸

(a) J. A. Gallagher, F. Macri, J. Bednarik, and F. 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.

⁸See footnote 1, page 10.

Composition A-3

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Composition: %		Molecular Weight: 227	
RDX	91	Oxygen Balance:	
Wax	9	CO ₂ %	-48
		CO %	-23
C/H Ratio		Density: gm/cc 12,000 psi	1.65
		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	100+	Refractive Index, n_D	
Sample Wt 20 mg		n _D	
Picatinny Arsenal Apparatus, in.	16	n _D	
Sample Wt, mg	17	n _D	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	0.3
		120°C	0.6
		135°C	
		150°C	
Rifle Bullet Impact Test: Trials		200 Gram Bomb Sand Test:	
Explosions	%	Sand, gm	51.5
Partials	0		
Burned	0		
Unaffected	100		
Explosion Temperature: °C		Sensitivity to Initiation:	
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		Ballistic Mortar, % TNT: (a)	135
75°C International Heat Test:		Treuzl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: (b)	
		Method	B B
100°C Heat Test:		Condition	Pressed Pressed
% Loss, 1st 48 Hrs	0.15	Confined	No No
% Loss, 2nd 48 Hrs	0.15	Density, gm/cc	1.61 1.20
Explosion in 100 Hrs	None	Brisance, % TNT ¹	126 75
Flammability Index: 195		Detonation Rate: (c)	
Hygroscopicity: % 30°C, 90% RH 0.0		Confinement	None
Volatility: 50°C, 15 days 0.03		Condition	Pressed
		Charge Diameter, in.	1.0
		Density, gm/cc	1.59
		Rate, meters/second	8100

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Composition A-3

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.62 Charge Wt, lb 2.102 Total No. of Fragments: For TNT 703 For Subject HE 1138 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.64 Charge Wt, lb 0.861 Total No. of Fragments: For TNT 514 For Subject HE 710	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White-buff Principal Uses: HE, SAP, AP projectiles; Shaped Charges Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft 2800 At 25½ ft 2530 Density, gm/cc 1.61	Loading Density: gm/cc psi x 10 ³ <div style="display: flex; justify-content: space-around;"> 3 12 </div> <div style="display: flex; justify-content: space-around;"> 1.47 1.65 </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Does not exude at 65°C when waxes melting sharply at or above 75°C are used.
	Preparation: 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. Effect of Temperature on Rate of Detonation: (e) <div style="display: flex; justify-content: space-around;"> <div> 16 hrs at, °C Density, gm/cc Rate, m/sec </div> <div> -54 1.51 7600 </div> <div> 21 1.51 7620 </div> </div> Booster Sensitivity Test: (d) <div style="display: flex; justify-content: space-around;"> <div> Condition Tetrayl, gm Wax, in. for 50% Detonation Density, gm/cc </div> <div> Pressed 100 1.70 1.62 </div> </div> Heat of: 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 waxes, 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:⁹

(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. Messel, 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:

<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>
1380	1451	1492	1493	1424	1325	1556	1687	1338	1639
1910	1761	2112		1614	1585	1936	1787	1388	2179
				1634	1595		1797	1728	
				2154	1715			1838	
					1885				
					2235				

⁹See footnote 1, page 10.

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Composition B

Composition: % RDX 60 TNT 40 Wax, added 1 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -43 CO % 10	
	Density: gm/cc	Cast 1.65
	Melting Point: °C	(1) 78-80
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
	Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	
Rifle Bullet Impact Test: Trials % Explosions 3 Partials 13 Burned 4 Unaffected 80	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.7 120°C 0.9 135°C 150°C 11+	
	200 Gram Bomb Sand Test: Sand, gm 54.0	
	Explosion Temperature: °C Second, 0.1 (no cap used) 526 1 368 5 Decomposes 278 10 255 15 > 250 20 > 250	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.20* Tetryl * Alternative initiating charges	
	Ballistic Mortar, % TNT: (a) 133	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None	Trauzl Test, % TNT: (b) 130	
	Plate Dent Test: (c) Method B Condition Cast Confined No Density, gm/cc 1.71 Brisance, % TNT 132	
	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.68 Rate, meters/second 7840	
Flammability Index: 177		
Hygroscopicity: % 30°C, 90% RH 0.02		
Volatility:		

Composition B

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Booster Sensitivity Test: (d) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.40 Wax, gm Density, gm/cc 1.69	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																				
Heat of: (e) Combustion, cal/gm 2790 Explosion, cal/gm 1240 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm (1) 8.0	Armor Plate Impact Test: (e) 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 209 Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches <table><tr><td></td><td><u>Trials</u></td><td><u>% Inert</u></td></tr><tr><td>1</td><td>4</td><td>100</td></tr><tr><td>1 1/4</td><td>6</td><td>50</td></tr><tr><td>1 1/2</td><td>2</td><td>0</td></tr><tr><td>1 3/4</td><td>0</td><td></td></tr></table>		<u>Trials</u>	<u>% Inert</u>	1	4	100	1 1/4	6	50	1 1/2	2	0	1 3/4	0						
	<u>Trials</u>	<u>% Inert</u>																			
1	4	100																			
1 1/4	6	50																			
1 1/2	2	0																			
1 3/4	0																				
Specific Heat: cal/gm/°C (1) <table><tr><td><u>°C</u></td><td></td><td><u>°C</u></td><td></td></tr><tr><td>-75</td><td>0.235</td><td>75</td><td>0.376</td></tr><tr><td>0</td><td>0.220</td><td>85</td><td>0.354</td></tr><tr><td>25</td><td>0.254</td><td>90</td><td>0.341</td></tr><tr><td>50</td><td>0.305</td><td>100</td><td>0.312</td></tr></table>	<u>°C</u>		<u>°C</u>		-75	0.235	75	0.376	0	0.220	85	0.354	25	0.254	90	0.341	50	0.305	100	0.312	
<u>°C</u>		<u>°C</u>																			
-75	0.235	75	0.376																		
0	0.220	85	0.354																		
25	0.254	90	0.341																		
50	0.305	100	0.312																		
Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C																					
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale:																					
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc																					
Compressive Strength: lb/inch² (b) 1610-2580 Density, gm/cc 1.68																					
Vapor Pressure: °C mm Mercury																					

Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: <table><tr><td></td><td><u>No Seal</u></td><td><u>Seal</u></td></tr><tr><td>Height, ft</td><td>4000</td><td>4000</td></tr><tr><td>Trials</td><td>65</td><td>39</td></tr><tr><td>Unaffected</td><td>58</td><td>36</td></tr><tr><td>Low Order</td><td>2</td><td>2</td></tr><tr><td>High Order</td><td>5</td><td>1</td></tr></table> 1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order		<u>No Seal</u>	<u>Seal</u>	Height, ft	4000	4000	Trials	65	39	Unaffected	58	36	Low Order	2	2	High Order	5	1
	<u>No Seal</u>	<u>Seal</u>																
Height, ft	4000	4000																
Trials	65	39																
Unaffected	58	36																
Low Order	2	2																
High Order	5	1																

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Composition B

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:		
90 mm HE, M71 Projectile, Lot WC-91:		<div>(g) (h) Glass Cones Steel Cones</div>		
Density, gm/cc	1.65	Hole Volume	178	162
Charge Wt, lb	2.187	Hole Depth	125	148
Total No. of Fragments:		Color: Yellow-brown		
For TNT	703	Principal Uses: Fragmentation bombs, HE projectiles, grenades, shaped charges		
For Subject HE	998			
3 inch HE, M42A1 Projectile, Lot KC-5:		Method of Loading: Cast		
Density, gm/cc	1.67	Loading Density: gm/cc 1.68		
Charge Wt, lb	0.882			
Total No. of Fragments:		Storage:		
For TNT	514			
For Subject HE	701			
Fragment Velocity: ft/sec		Method Dry		
At 9 ft	2940			
At 25½ ft	2680	Hazard Class (Quantity-Distance) Class 9		
Density, gm/cc	1.68			
Blast (Relative to TNT): (f)		Compatibility Group Group I		
Air:				
Peak Pressure	110	Exudation Very slight when stored at 71°C		
Impulse	110			
Energy	116	Origin:		
Air, Confined:				
Impulse	75	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.		
Under Water:				
Peak Pressure	110	Effect of Temperature on Rate of Detonation: (i)		
Impulse	108			
Energy	121	16 hrs at, °C -54 24		
Underground:		Density, gm/cc 1.69 1.69		
Peak Pressure	104	Rate, m/sec 7720 7660		
Impulse	97	Bulk Modulus at Room Temperature (25°-30°C): (j)		
Energy		% Wax in Comp B 1 2 3		
Crater radius cubed	107	Dynes/cm ² x 10 ⁻¹⁰ 5.10 3.56 2.34		
		Density, gm/cc 1.72 1.70 1.68		
		Viscosity, poises:		
		Temp, 83°C 3.1		
		95°C 2.7		

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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 TNT 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:¹⁰

- (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 Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Divisions 2 and 8, NDRC, Report on HBX 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 W672-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, PATR No. 2383, November, 1956.

¹⁰See footnote 1, page 10.

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Composition B

(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:

<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>
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	1737	1458	1819
2190			2053	2104	1865	1956	1797	1688	2019
			2063		1885	2236	2007	1728	
			2103		2055		2147	1828	
			2233		2125			1838	
					2155			1978	
					2175			2008	
					2235			2138	
								2168	

(l) C. Lenchitz, W. Beach and R. Valicky, 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**
% RDX		60	55.2			See Cyclonite	See Comp B
TNT		40	40.0	Oxygen Balance:		See Cyclonite	See Comp B
Wax, added, (Stanolind or Aristovax, 1650/1700F)		5		CO ₂ %		See Cyclonite	See Comp B
Vinylseal (MA28-14), added		2		CO %		See Cyclonite	See Comp B
Vistanex (B120)			1.2	Density: gm/cc		Cast	1.65
Albacor Wax			3.6	Melting Point: °C			
C/H Ratio				Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt:		I*	II**	Boiling Point: °C			
Bureau of Mines Apparatus, cm		95		Refractive Index, n _D ²⁰			
Sample Wt 20 mg				n _D ²⁵			
Picatinny Arsenal Apparatus, in.		14	13	n _D ³⁰			
Sample Wt, mg		17	16	Vacuum Stability Test:		I*	II**
Friction Pendulum Test:				cc/40 Hrs, at			
Steel Shoe		Unaffected		90°C			
Fiber Shoe		Unaffected		100°C			
Rifle Bullet Impact Test:				120°C		0.99	0.92
Trials				135°C			
% I*		I*	II**	150°C		11+	11+
Explosions		0	0	200 Gram Bomb Sand Test:		I*	II**
Partials		0	0	Sand, gm		52.7	55.0
Burned		5	0	Sensitivity to Initiation:		I*	II**
Unaffected		95	100	Minimum Detonating Charge, gm			
Explosion Temperature: °C		I*	II**	Mercury Fulminate			
Seconds, 0.1 (no cap used)				Lead Azide		0.22	0.26
1				Tetryl			
5 Decomposes		260	270	Ballistic Marker, % TNT:			
10				T.Just Test, % TNT:			
15				Plate Dent Test:			
20				Method			
75°C International Heat Test:				Condition			
% Loss in 48 Hrs				Confined			
100°C Heat Test:		I*	II**	Density, gm/cc			
% Loss, 1st 48 Hrs		0.05	0.12	Brisance, % TNT			
% Loss, 2nd 48 Hrs		0.19	0.18	Detonation Rate:			
Explosion in 100 Hrs		None	None	Confinement			
Flammability Index:				Condition			
Hygroscopicity: %				Charge Diameter, in.			
30°C, 90% RH		0.00	0.00	Density, gm/cc			
Volatility:		Nil	Nil	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

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, 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 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: Yellow-brown Principal Uses: Bombs Method of Loading: Cast Leading Density: gm/cc 1.65 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Viscosity, poises: I* II** Temp, 83°C 3.5 3.1 95°C 2.6 2.7 References: (a) See the following Picatinny Arsenal Technical Reports on RDX Composition B, Desensitized: 1 3 5 6 2701 1313 1435 1756 2053 1865
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*Desensitized Comp B, designated I, uses emulsified wax.

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

Composition C

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

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Composition C

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

Composition C-2

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Composition:		Molecular Weight:	
%		Oxygen Balance:	
RDX	78.7	CO ₂ %	
TNT	5.0	CO %	
DNT	12.0	Density: gm/cc	
MNT	2.7	Melting Point: °C	
NC	0.6	Freezing Point: °C	
Solvent	1.0	Boiling Point: °C	
C/H Ratio		Refractive Index, n_D²⁰	
Impact Sensitivity, 2 Kg Wt:		n_D²⁵	
Bureau of Mines Apparatus, cm	90	n_D³⁰	
Sample Wt 20 mg		Vacuum Stability Test:	
Picatinny Arsenal Apparatus, in.		cc/40 Hrs, at	
Sample Wt, mg		90°C	
Friction Pendulum Test:		100°C	2.0
Steel Shoe		120°C	9.0
Fiber Shoe		135°C	
Rifle Bullet Impact Test: Trials		150°C	
	%	200 Gram Bomb Sand Test:	
Explosions	0	Sand, gm	47.5
Partials	20	Sensitivity to Initiation:	
Burned	0	Minimum Detonating Charge, gm	
Unaffected	80	Mercury Fulminate	
Explosion Temperature: °C		Lead Azide	0.25
Seconds, 0.1 (no cap used)		Tetryl	0.10
1		Ballistic Mortar, % TNT: (a)	
5 Decomposes	285	126	
10		Trauzl Test, % TNT:	
15		Plate Dent Test: (c)	
20		Method	B
73°C International Heat Test:		Condition	Hand tamped
% Loss in 48 Hrs		Confined	No
100°C Heat Test:		Density, gm/cc	1.52
% Loss, 1st 48 Hrs	1.8	Brisance, % TNT	111
% Loss, 2nd 48 Hrs	1.4	Detonation Rate: (d)	
Explosion in 100 Hrs	None	Confinement	None
Flammability Index:		Condition	Hand tamped
	178	Charge Diameter, in.	1.0
Hygroscopicity: % 30°C, 95% RH		Density, gm/cc	1.57
	0.55	Rate, meters/second	7660
Volatility: 25°C, 5 days			
	0.00		

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Composition C-2

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.57
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-around;"> Exudation Volatilizes above 52°C </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Plasticity: <div style="display: flex; justify-content: space-around;"> <div> Below 0°C 0-40°C above 40°C </div> <div> Plastic (-30°C) Plastic Hard (52°C)* </div> </div> *Due to volatilization of plasticizer. References: See references for Composition C-4.

Composition C-3

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Composition:		Molecular Weight:	
%		Oxygen Balance:	
RDX	77	CO ₂ %	
Tetryl	3	CO %	
TNT	1	Density: gm/cc	
DNT	10	Melting Point: °C	
MNT	5	Freezing Point: °C	
NC	1	Boiling Point: °C	
C/H Ratio		Refractive Index, n_D²⁰	
Impact Sensitivity, 2 Kg Wt:		Vacuum Stability Test:	
Bureau of Mines Apparatus, cm	100+	cc/40 Hrs, at	
Sample Wt 20 mg		90°C	
Picatinny Arsenal Apparatus, in.	14	100°C	
Sample Wt, mg	33	120°C	
Friction Pendulum Test:		135°C	
Steel Shoe	Unaffected	150°C	
Fiber Shoe	Unaffected	200 Gram Bomb Sand Test:	
Rifle Bullet Impact Test:		Sand, gm	
	Trials	53.1	
	%	Sensitivity to Initiation:	
Explosions	0	Minimum Detonating Charge, gm	
Partials	40	Mercury Fulminate	
Burned	0	Lead Azide	
Unaffected	60	Tetryl	
Explosion Temperature: °C		Ballistic Mortar, % TNT: (a)	
Seconds, 0.1 (no cap used)		126	
1		Trauzl Test, % TNT: (b)	
5 Decomposes	280	117	
10		Plate Dent Test: (c)	
15		Method	
20		Condition	
75°C International Heat Test:		Confined	
% Loss in 48 Hrs		Density, gm/cc	
100°C Heat Test:		Brisance, % TNT	
% Loss, 1st 48 Hrs	3.20	Detonation Rate: (d)	
% Loss, 2nd 48 Hrs	1.63	Confinement	
Explosion in 100 Hrs	None	Condition	
Flammability Index:		Charge Diameter, in.	
Hygroscopicity: % 30°C, 95% RH		Density, gm/cc	
Volatility: 25°C, 5 days		Rate, meters/second	
		7625	

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Composition C-3

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 158 Charge Wt, lb 2045 Total No. of Fragments: For TNT 703 For Subject HE 944 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.60 Charge Wt, lb 0.842 Total No. of Fragments: For TNT 514 For Subject HE 671	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.58
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 77°C
Blast (Relative to TNT). Air: Peak Pressure 105 Impulse 109 Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Plasticity: <div style="display: flex; justify-content: space-around;"> <div> Below 0°C 0-40°C Above 40°C </div> <div> Hard (-29°C) Plastic Exudes (77°C) </div> </div> Booster Sensitivity Test: (h) <div style="display: flex; justify-content: space-around;"> <div> Condition Teteryl, gm Wax, in. for 50% Detonation Density, gm/cc </div> <div> Pressed 100 1.36 1.62 </div> </div> References: See references for Composition C-4.

Composition C-4

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Composition:		Molecular Weight:	
%		Oxygen Balance:	
RDX	91	CO ₂ %	
Plasticizer, non-explosive	9*	CO %	
* Contains polyisobutylene 2.1%; motor oil 1.6% and di(2-ethylhexyl) sebacate 5.3%.		Density: gm/cc	
C/H Ratio		Melting Point: °C	
Impact Sensitivity, 2 Kg Wt:		Freezing Point: °C	
Bureau of Mines Apparatus, cm	100+	Boiling Point: °C	
Sample Wt 20 mg		Refractive Index, n_D²⁰	
Picatinny Arsenal Apparatus, in.	19	n _D ²⁰	
Sample Wt, mg	27	n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test:		100°C	
Trials		120°C	
Explosions	0	135°C	
Portals	0	150°C	
Burned	20	200 Gram Bomb Sand Test:	
Unaffected	80	Sand, gm	
Explosion Temperature: °C		55.7	
Seconds, 0.1 (no crp used)		Sensitivity to Initiation:	
1		Minimum Detonating Charge, gm	
5	290	Mercury Fulminate	
10		Lead Azide	
15		Tetryl	
20		0.20	
75°C International Heat Test:		0.10	
% Loss in 48 Hrs		Ballistic Mortar, % TNT: (a)	
100°C Heat Test:		130	
% Loss, 1st 48 Hrs	0.13	Treuzl Test, % TNT:	
% Loss, 2nd 48 Hrs	0.00	Plate Dent Test: (c)	
Explosion in 100 Hrs	None	Method	
Flammability Index:		B	
Hygroscopicity: % 30°C, 95% RH		Condition	
Nil		Hand tamped	
Volatility:		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	
		2040	

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Composition C-4

Fragmentation Test: 90 mm HE, M73 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	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light brown Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 1.60 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 77°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Effect of Temperature on Rate of Detonation: (1) <div style="display: flex; justify-content: space-between;"> <div> 16 hrs at, °C Density, gm/cc Rate, m/sec </div> <div style="display: flex; align-items: center;"> <div style="text-align: center;"> -54 1.36 7020 </div> <div style="text-align: center; padding: 0 10px;"> 21 1.35 7040 </div> </div> </div> Plasticity: <div style="display: flex; justify-content: space-between;"> <div> Below 0°C 0-40°C Above 40°C </div> <div style="text-align: right;"> Plastic (-57°C) Plastic Plastic (77°C) </div> </div>

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

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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 44 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:¹¹

- (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 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. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (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) 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 W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.
- (h) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

¹¹See footnote 1, page 10.

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

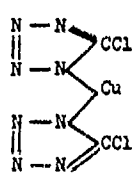
(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2383, November 1956.

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

	<u>C</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
<u>Comp C</u>	1260		1293					1518 1838	
<u>Comp C-2</u>			1293			1416		1518	
<u>Comp C-3</u>		1611	1713	2154	1595 1695 1885	1416 1556 1766	1797	1518 2028	
<u>Comp C-4</u>						1766	1907	1828 1958	1819

Copper Chlorotetrazole

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Composition: % C 8.9 N 41.5 Cl 26.2 Cu 23.4 C/H Ratio		Molecular Weight: ($\text{CuC}_2\text{N}_8\text{Cl}_2$) 271 Oxygen Balance: CO_2 % -30 CO % -18 Density: gm/cc 2.04 Melting Point: °C Freezing Point: °C	
		Boiling Point: °C Refractive Index: n_D^{20} n_D^{25} n_D^{30}	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 1; (1 lb wt) 3 Sample Wt, mg 9		Friction Pendulum Test: Steel Shoe Exploded Fiber Shoe Exploded	
Rifle Bullet Impact Test: Trials % Explosions Partial 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 5 305 10 15 20		200 Grain Bomb Sand Test: (g) Sand, gm 27.4 Black Powder Fuse 25.3 17.0	
75°C International Heat Test: % Loss in 48 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 0.30 Tetrayl 0.10	
100°C Heat Test: % Loss, 1st 48 Hrs 2.57 % Loss, 2nd 48 Hrs 0.10 Explosion in 100 Hrs None		Ballistic Measure, % TNT: Transit Test, % TNT:	
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 30°C, 90% RH 3.11		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:			

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Copper Chlorotetrazole

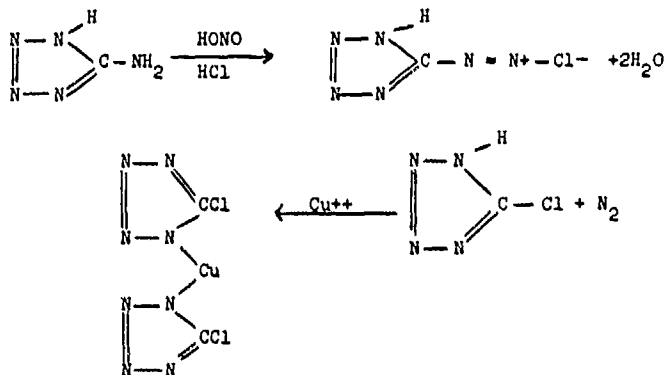
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Blue
	Principal Uses: Primary explosive
	Method of Loading: Pressed
	Loading Density: gm/cc psi x 10 ³ (c) 10 20 40 70 1.49 1.63 1.74 1.86
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Stab Sensitivity: (c) Density Firing Point (inch-ounces) gm/cc 0% 50% 100% 1.49 9 11 15 1.63 8.5 10 12 1.74 6 7 9 1.86 4 5 6 Heat of: Explosion, cal/gm 432 Specific Heat, cal/gm/°C Temp range 0°-30°C 0.155 Wt of sample, gm 0.8910

Copper Chlorotetrazole

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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°-15°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 5 gms 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 74%.

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:¹²

(a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.

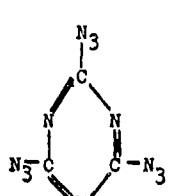
(b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances for Application in Ammunition, PATR No. 2179, May 1955.

(c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimum Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Compounds, PATR No. 2146, February 1955.

¹²See footnote 1, page 10.

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Cyanuric Triazide

Composition: % C 17.6 N 82.4  C/H Ratio	Molecular Weight: (C ₃ H ₃ N ₆) 204 Oxygen Balance: CO ₂ % -47.1 CO % -23.5 Density: gm/cc Crystal 1.54 Melting Point: °C 94 Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. - Sample Wt, mg -	Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 32.2
Explosion Temperature: °C Seconds, 0.1 (no cap used) 252 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate - Lead Azide 0.20 Tetryl 0.10
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Treuzl Test, % TNT:
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Hygroscopicity: %	Detonation Rate: Confinement - Condition - Charge Diameter, in. 0.3 Density, gm/cc 1.15 Rate, meters/second 5550-5600
Volatility: Decomposes above 100°C	

Cyanuric Triazide

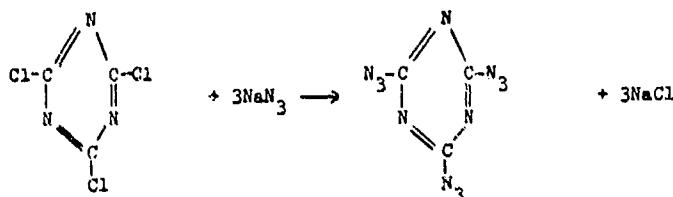
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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Colorless
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Not used because of difficulty in controlling sensitivity.
	Method of Loading: Pressed
	Loading Density: gm/cc At 200 atmospheres 1.4 At 800 atmospheres 1.5
	Storage: Method Hazard Class (Quantity-Distance) Class 9 Compatibility Group -- -- Exudation None

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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:¹³

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

(b) Ott and Ohse, Ber 54, 179 (1921).

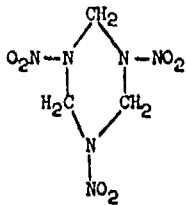
(c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923).

Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

¹³See footnote 1, page 10.

Cyclonite* (RDX)

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Composition: % C 16.3 H 2.7 N 37.8 O 43.2 C/H Ratio 0.095		Molecular Weight: (C ₃ H ₆ N ₆ O ₆) 222 Oxygen Balance: CO ₂ % -22 CO % 0.0 Density: gm/cc Crystal 1.82 Melting Point: °C 204 Freezing Point: °C	
		Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 8 Sample Wt, mg 18		Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Unaffected	
Rifle Bullet Impact Test: Trials Explosions % 100 Partial 0 Burned 0 Unaffected 0		Vacuum Stability Test: cc/40 Hrs, at 100°C 0.7 120°C 0.9 135°C - 150°C 2.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 405 1 316 5 Decomposes 260 10 240 15 235 20 -		200 Gram Bomb Sand Test: Sand, gm 60.2	
75°C International Heat Test: % Loss in 48 Hrs 0.03		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.19* Lead Azide 0.05* Tetryl - * Alternative initiating charges.	
100°C Heat Test: % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Ballistic Mortar, % TNT: (a) 150 Treuzl Test, % TNT: (b) 157	
Flammability Index: (d) 278		Plate Dent Test: (c) Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 135	
Hygroscopicity: % 25°C, 100% RH 0.02		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.65 Rate, meters/second 8180	
Volatility: Nil			

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

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Cyclonite (RDX)

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (1) (Z/sec) 10 ^{18.5} Heat, kilocalorie/mole (ΔH, kcal/mol) 47.5 Temperature Range, °C 213-299 Phase Liquid																				
Heat of: Combustion, cal/gm 2285 Explosion, cal/gm 1280 Gas Volume, cc/gm 908 Formation, cal/gm -96 Solution, cal/mol (28-55% HNO ₃) 7.169* *Assuming cyclonite unimolecular	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾																				
Specific Heat: cal/gm/°C <table><thead><tr><th>°C</th><th></th><th>°C</th><th></th></tr></thead><tbody><tr><td>20</td><td>0.298</td><td>100</td><td>0.406</td></tr><tr><td>40</td><td>0.331</td><td>120</td><td>0.427</td></tr><tr><td>60</td><td>0.360</td><td>140</td><td>0.446</td></tr><tr><td>80</td><td>0.384</td><td></td><td></td></tr></tbody></table>	°C		°C		20	0.298	100	0.406	40	0.331	120	0.427	60	0.360	140	0.446	80	0.384			Bomb Drop Test: 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
°C		°C																			
20	0.298	100	0.406																		
40	0.331	120	0.427																		
60	0.360	140	0.446																		
80	0.384																				
Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C 1.263 Density, gm/cc 1.533	(h) 6.91 x 10 ⁻⁴ 6.98 x 10 ⁻⁴																				
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale: 2.5																					
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc																					
Compressive Strength: lb/inch²																					
Vapor Pressure: °C mm Mercury																					

Cyclonite (RDX)

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Detonator base charge, and ingredient for projectile and bomb fillers Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc psi x 10³ <div style="display: flex; justify-content: space-around;"> <div>3 1.46</div> <div>5 1.52</div> <div>10 1.60</div> <div>12 1.63</div> <div>15 1.65</div> <div>20 1.68</div> </div> Storage: <div style="display: flex; justify-content: space-between;"> Method Wet </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group M (wet) Group L (dry) </div> <div style="display: flex; justify-content: space-between;"> Exudation None </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Effect of Temperature on Rate of Detonation: (k) <div style="display: flex; justify-content: space-around;"> 16 hrs at, °C -54 21 </div> <div style="display: flex; justify-content: space-around;"> Density, gm/cc 1.61 1.62 </div> <div style="display: flex; justify-content: space-around;"> Rate, m/sec 8100 8050 </div> Effect of Temperature on Impact Sensitivity: <div style="display: flex; justify-content: space-around;"> <div>Temp. °C</div> <div>PA Impact Test 2Kg Wt, inches</div> </div> <div style="display: flex; justify-content: space-around;"> Room 9 </div> <div style="display: flex; justify-content: space-around;"> 32.2 8 </div> <div style="display: flex; justify-content: space-around;"> 104 5 </div>

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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>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
30	0.005	0	0.040	0	4.4	20	0.05	0	0.015
50	0.025	20	0.105	20	7.3	40	0.09	20	0.02
70	0.076	40	0.240	40	11.5	60	0.20	40	0.05
90	0.19	60	0.579	60	18.	80	0.41	60	0.13
100	0.28	78	1.195					80	0.30
								100	0.65
<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Methanol</u>		<u>Ether</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
28	2.9	50	0.005	0	0.14	10	0.05	80	4.4
94	18.	60	0.007	20	0.23	20	0.056	85	5.0
		70	0.009	40	0.47	30	0.076	90	5.55
				60	1.1			95	6.2
								100	7.0
								105	7.9
<u>Isomyl alcohol</u>		<u>Methyl acetate</u>		<u>β-Ethoxyethyl acetate</u>		<u>Chlorobenzene</u>		<u>Trichloroethylene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.02	20	2.9	20	0.15	20	0.33	20	0.20
20	0.03	30	3.2	30	0.16	30	0.44	30	0.22
40	0.065	40	4.1	40	0.19	40	0.56	40	0.24
60	0.22	50	5.6	50	0.25	50	0.74	50	0.26
80	0.54								
100	1.35								
<u>Tetra-chloroethane</u>		<u>Isopropanol</u>		<u>Isobutanol</u>		<u>Chloroform</u>		<u>Mesityloxide</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
38	0.09	38	0.18	20	0.0	20	0.01	27	3.2
								97	12.2
<u>Cyclo-hexanone</u>		<u>Nitro-benzene</u>		<u>Nitro-ethane</u>		<u>Cyclo-pentanone</u>		<u>Acetonitrile</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
25	12.7	25	1.5	28	3.6	28	11.5	28	11
97	25	97	12.4	93	19	90	37	82	33
<u>Methyl ethyl ketone</u>									
<u>°C</u>	<u>%</u>								
28									
95									

Cyclonite (RDX)

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

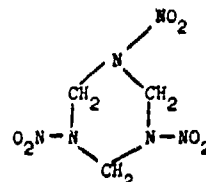
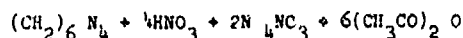
<u>Solvent</u>	<u>Boiling Point, °C</u>	<u>Grade or Source*</u>	<u>Solubility</u>		<u>Crystalline Form</u>
			<u>28°C</u>	<u>Heated</u>	
Acetone	56	CP	8.2	16.5 at 60°C	hexagonal-thick
Cyclohexanone	155.6	CP	13.0	24.0 at 93°C	cubic (massive form)
Nitromethane	100.8		1.5	12.4 at 97°C	plates
Acetonitrile	81.6	Miacet 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 CP	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	3.7 at 93°C	prisms
Isoamylacetate	132	CP	1.2	5.6 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	Cyanamid Co.	4.0	16.4 at boil.	flat plates
Methylcellosolveacetate	144.5	Carbide & Carbon	1.6	8.8 at 93°C	massive hexagons and prisms

* EK, Eastman Kodak; Pract, practical.

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Cyclonite (RDX)Preparation:

(Summary Technical Report of the WDRC, 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 195°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 β -RDX. The preparative procedure described above, the Bachmann or Conination process, yields cyclonite containing 3-8% RMX.

Origin:

First prepared by Hennin in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1,102,693) 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:¹⁴

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

¹⁴See footnote 1, page 10.

Cyclonite (RDX)

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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 2561, First Report, August 1942.

(i) R. J. Finkelstein and G. Gamov, 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, NATH No. 2333, 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	532	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	1685	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	1907		
	2151				2305	1936	2147		
						1956	2227		
						2016			
						2056			
						2176			

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Cyclotol, 75/25

Composition: % RDX 75 TNT 25 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -35 CO % -6	
	Density: gm/cc	Cast 1.71
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.23 120°C 0.41 135°C - 150°C -	
Rifle Bullet Impact Test: Trials Explosions % 30 Partial Smokes 40 Burned 0 Unaffected 30	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Treuzl Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None None Condition Cast Cast Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.70 1.71 Rate, meters/second 8035 7938	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Cyclotol, 75/25

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Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase																				
Heat of: Combustion, cal/gm 2625* Explosion, cal/gm 1225* Gas Volume, cc/gm 862 Formation, cal/gm Fusion, cal/gm (h) 5.0 *Calculated from composition of mixture.	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4																				
Specific Heat: cal/gm/°C (h) <table><tr><th colspan="2">°C</th><th colspan="2">°C</th></tr><tr><td>-75</td><td>0.220</td><td>75</td><td>0.352</td></tr><tr><td>0</td><td>0.225</td><td>85</td><td>0.325</td></tr><tr><td>25</td><td>0.254</td><td>90</td><td>0.332</td></tr><tr><td>50</td><td>0.296</td><td>100</td><td>0.351</td></tr></table>	°C		°C		-75	0.220	75	0.352	0	0.225	85	0.325	25	0.254	90	0.332	50	0.296	100	0.351	Bomb Drop Test: 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
°C		°C																			
-75	0.220	75	0.352																		
0	0.225	85	0.325																		
25	0.254	90	0.332																		
50	0.296	100	0.351																		
Burning Rate: cm/sec																					
Thermal Conductivity: cal/sec/cm/°C																					
Coefficient of Expansion: Linear, %/°C Volume, %/°C																					
Hardness, Mohs' Scale:																					
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc																					
Compressive Strength: lb/inch²																					
Vapor Pressure: °C mm Mercury																					

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Cyclotol, 75/25

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.72 Charge Wt, lb 2.22 Total No. of Fragments: For TNT 703 For Subject HE 1514 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones Hole Volume Hole Depth </div> Color: Yellow-buff Principal Uses: Shaped charge bomb especially fragmentation; HE projectiles; grenades Method of Loading: Cast Loading Density: gm/cc 1.71
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): (d) Air: Peak Pressure 111 Impulse 126 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Preparation: See Composition B Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II. Black Modulus at Room Temperature (25°-30°C): <div> Dynes/cm² x 10⁻¹⁰ 3.09 Density, gm/cc 1.74 </div> Absolute Viscosity, poises:* <div> Temp, 85°C 210** 90°C -- </div> Efflux Viscosity, Saybolt Seconds: <div> Temp, 85°C 9-14 </div> * Compositions using Spec Grade Type A, Class A RDX. ** Composition prepared using RDX of optimum particle size.

Cyclotol, 70/30

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Composition: %		Molecular Weight: 224	
RDX	70	Oxygen Balance: CO ₂ % -37 CO % -8	
TNT	30	Density: gm/cc Cast 1.71	
C/H Ratio		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	60	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.	14		
Sample Wt, mg	20		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at 90°C	
Fiber Shoe	Unaffected	100°C	
Rifle Bullet Impact Test: Trials		120°C 0.86	
	%	135°C	
Explosions	30	150°C	
Partials	30		
Burned	0	200 Gram Bomb Sand Test:	
Unaffected	40	Sand, gm 96.6	
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	-	Minimum Detonating Charge, gm	
1	-	Mercury Fulminate 0.21*	
5 Decomposes	265	Lead Azide 0.20*	
10		Tetryl	
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT: (a) 135	
75°C International Heat Test:		Truax Test, % TNT:	
% Loss in 48 Hrs			
100°C Heat Test:		Plate Dent Test: (b)	
% Loss, 1st 48 Hrs	0.07	Method B	
% Loss, 2nd 48 Hrs	0.08	Condition Cast	
Explosion in 100 Hrs	None	Confined No	
Flammability Index:		Density, gm/cc 1.725	
		Brisance, % TNT 136	
Hygroscopicity: % Nil		Detonation Rate:	
		Confinement None	
Volatility: Nil		Condition Cast	
		Charge Diameter, in. 1.0	
		Density, gm/cc 1.73	
		Rate, meters/second 8060	

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Cyclotol, 70/30

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.71 Charge Wt, lb 2.213 Total No. of Fragments: For TNT 703 For Subject HE 1165 3 inch HE, JA42A1 Projectile, Lot KC-5: Density, gm/cc 1.72 Charge Wt, lb 0.923 Total No. of Fragments: For TNT 514 For Subject HE 828	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones (e) </div> Hole Volume Hole Depth 130 Color: Yellow-buff Principal Uses: Shaped charge bombs; especially fragmentation HE projectiles, grenades Method of Loading: Cast Loading Density: gm/cc 1.71
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): (d) Air: Peak Pressure 110 Impulse 120 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Preparation: See Composition B Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II. Absolute Viscosity, poises:* Temp, 85°C -- 90°C 53.2 Efflux Viscosity, Saybolt Seconds: 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 composition of mixture.

Cyclotol, 65/35

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Composition: % RDX 35 TNT 35 C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO ₂ % -40 CO % -9	
	Density: gm/cc	Cast 1.71
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 55.4	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 3 Decomposes 270 10 15 20	Ballistic Mortar, % TNT: (a) 134	
75°C International Heat Test: % Loss in 48 Hrs	Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm, cc 1.72 Rate, meters/second 7975	
Hygroscopicity: % Nil		
Volatility: Nil		

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Cyclotol, 65/35

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:												
90 mm HE, M71 Projectile, Lot WC-91:	<table><tr><td></td><td>Glass Cones</td><td>Steel Cones</td><td>(e)</td></tr><tr><td>Density, gm/cc</td><td>1.71</td><td></td><td></td></tr><tr><td>Charge Wt, lb</td><td>2.253</td><td>130</td><td></td></tr></table>		Glass Cones	Steel Cones	(e)	Density, gm/cc	1.71			Charge Wt, lb	2.253	130	
	Glass Cones	Steel Cones	(e)										
Density, gm/cc	1.71												
Charge Wt, lb	2.253	130											
Total No. of Fragments:	Color: Yellow-buff												
For TNT 703													
For Subject HE 1153													
3 inch HE, M42A1 Projectile, Lot KC-5:	Principal Uses: Shaped charge bombs; especially fragmentation HE projectiles, grenades												
Density, gm/cc 1.71													
Charge Wt, lb 0.922													
Total No. of Fragments:	Method of Loading: Cast												
For TNT 514													
For Subject HE 769													
Fragment Velocity: ft/sec	Loading Density: gm/cc 1.71												
At 9 ft													
At 25½ ft													
Density, gm/cc													
Blast (Relative to TNT):	Storage:												
Air:	Method Dry												
Peak Pressure													
Impulse	Hazard Class (Quantity-Distance) Class 9												
Energy	Compatibility Group Group I												
Air, Confined:	Exudation												
Impulse													
Under Water:	Preparation: See Composition B												
Peak Pressure	Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.												
Impulse	Eutectic Temperature, °C: 79												
Energy													
Underground:	gm RDX/100 gm TNT												
Peak Pressure	79°C 4.16												
Impulse	95°C 5.85												
Energy	Absolute Viscosity, poises:*												
Heat of: *	Temp, 85°C 30.2												
Combustion, cal/gm 2755	90°C 26.0												
Explosion, cal/gm 1205													
Gas Volume, cc/gm 845													
* Calculated from composition of mixture.	* Composition using Spec Grade Type A, Class A RDX.												

Cyclotol, 60/40

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Composition: %		Molecular Weight: 224	
RDX	60	Oxygen Balance: CO ₂ % -43 CO % 10	
TNT	40	Density: gm/cc Cast 1.68	
C/H Ratio		Melting Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19		Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Boiling Point: °C	
Rifle Bullet Impact Test: Trials Explosions % Partials 55 Burned 25 Unaffected 15		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.29 135°C 150°C	
75°C International Heat Test: % Loss in 48 Hrs		200 Gram Bomb Sand Test: Sand, gm 54.6	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.20* Tetryl *Alternative initiating charges.	
Flammability Index:		Ballistic Mortar. % TNT: (a) 1.33	
Hygroscopicity: % Nil		Trauzl Test, % TNT:	
Volatility: Nil		Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.72 Brisance, % TNT 132	
		Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.72 Rate, meters/second 7900	

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Cyclotol, 60/40

Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100:												
90 mm HE, M71 Projectile, Lot WC-91:	<table><tr><td></td><td>Glass Cones</td><td>Steel Cones</td><td>(e)</td></tr><tr><td>Density, gm/cc</td><td>1.65</td><td>162</td><td></td></tr><tr><td>Charge Wt, lb</td><td>2.187</td><td>148</td><td></td></tr></table>		Glass Cones	Steel Cones	(e)	Density, gm/cc	1.65	162		Charge Wt, lb	2.187	148	
	Glass Cones	Steel Cones	(e)										
Density, gm/cc	1.65	162											
Charge Wt, lb	2.187	148											
Total No. of Fragments:	Color: Yellow-buff												
For TNT 703													
For Subject HE 798													
3 inch HE, M42A1 Projectile, Lot KC-5:	Principal Uses: Shaped charge bomb; especially fragmentation HE projectiles, grenades												
Density, gm/cc 1.67													
Charge Wt, lb 0.882													
Total No. of Fragments:	Method of Loading: Cast												
For TNT 514													
For Subject HE 701													
Fragment Velocity: ft/sec (c)	Loading Density: gm/cc 1.68												
At 9 ft 2965													
At 25 1/2 ft 2900													
Density, gm/cc --													
Blast (Relative to TNT): (d)	Storage:												
Air:	Method Dry												
Peak Pressure 104													
Impulse 116	Hazard Class (Quantity-Distance) Class 9												
Energy --	Compatibility Group Group I												
Air, Confined:	Exudation												
Impulse													
Under Water:	Preparation: See Composition B												
Peak Pressure	Origin: Developed by the British between World Wars I and II and standardized in the United States early in World War II.												
Impulse	Bulk Modulus at Room Temperature (25°-30°C):												
Energy	Dynes/cm ² x 10 ⁻¹⁰ 4.14												
Underground:	Density, gm/cc 1.72												
Peak Pressure	Absolute Viscosity, poises:*												
Impulse	Temp, 85°C 12.3												
Energy	90°C --												
Heat of: *	* Compositions using Spec Grade Type A, Class A RDX.												
Combustion, cal/gm 2820													
Explosion, cal/gm 1195													
Gas Volume, cc/gm 845													
Compressive Strength: lb/inch²													
1.70 gm/cc 2200-3000													

* Calculated from composition of mixture.

Cyclotol, 75/25, 70/30, 65/35

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References: 15

(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) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 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, NDRC 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:

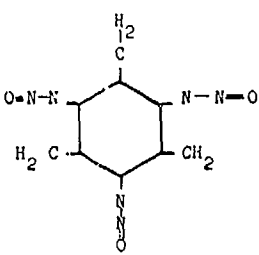
<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1290	1651	1482	1483	1824	1435	1476	1427	1398	1469
1530	1741		1793	1834	1585	1756	1507	1488	1509
			1983	1944		1796	1747	1838	1709
				2004		1876			

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

¹⁵See footnote 1, page 10.

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Cyclotrimethylene Trinitrosamine

Composition: % C 20.6 H 3.5 N 48.3 O 27.6 C/H Ratio 0.12		Molecular Weight: (C ₃ H ₆ N ₆ O ₃) 174
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Oxygen Balance: CO ₂ % -55 CO % -28	Density: gm/cc
		Melting Point: °C 105 to 107
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Freezing Point: °C	Boiling Point: °C
	Refractive Index, n_D²⁰ n _D ²⁵ n _D ³⁰	Vacuum Stability Test: (c) cc/40 Hrs, at 90°C 0.20 100°C 9.19 3.71* *Average value of 5 gm sample twice recrystallized from isoamyl alcohol.
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 59.2 54.1	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.200** Lead Azide 0.100** Tetryl **Alternative initiating charges.
		Ballistic Mortar, % TNT: 130
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 220 10 15 20	Trauzl Test, % TNT:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
	75°C International Heat Test: % Loss in 48 Hrs	
100°C Heat Test: % Loss, 1st 48 Hrs 8.79 % Loss, 2nd 48 Hrs 2.98 Explosion in 100 Hrs None	Flammability Index:	Detonation Rate: (b)
	Hygroscopicity: % 30°C, 90% RH 0.02	Confinement None
Volatility:	Condition Cast	Charge Diameter, in. 1.2
	Density, gm/cc 1.42	Density, gm/cc 1.42
Rate, meters/second 7000 to 7300		

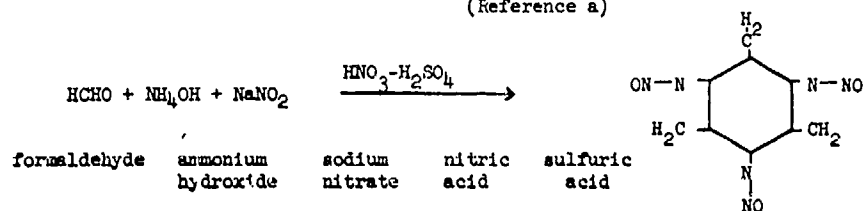
Cyclotrimethylene Trinitrosamine

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow Principal Uses: Ingredient of projectile filler Method of Loading: Pressed or cast with added melting point depressants Loading Density: gm/cc See below																														
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M Exudation None																														
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Density at Various Pressures: (b) <table><tr><th></th><th><u>lb/inch²</u></th><th><u>gm/cc</u></th></tr><tr><td></td><td>2,420</td><td>1.10</td></tr><tr><td></td><td>4,830</td><td>1.23</td></tr><tr><td></td><td>9,650</td><td>1.37</td></tr><tr><td></td><td>14,500</td><td>1.44</td></tr><tr><td></td><td>24,200</td><td>1.53</td></tr><tr><td></td><td>33,800</td><td>1.57</td></tr><tr><td></td><td>42,500</td><td>1.59</td></tr></table> Heat of: <table><tr><td>Combustion, cal/gm</td><td>3158</td></tr><tr><td>Explosion, cal/gm</td><td>876</td></tr><tr><td>Formation, cal/gm</td><td>-914</td></tr></table>		<u>lb/inch²</u>	<u>gm/cc</u>		2,420	1.10		4,830	1.23		9,650	1.37		14,500	1.44		24,200	1.53		33,800	1.57		42,500	1.59	Combustion, cal/gm	3158	Explosion, cal/gm	876	Formation, cal/gm	-914
	<u>lb/inch²</u>	<u>gm/cc</u>																													
	2,420	1.10																													
	4,830	1.23																													
	9,650	1.37																													
	14,500	1.44																													
	24,200	1.53																													
	33,800	1.57																													
	42,500	1.59																													
Combustion, cal/gm	3158																														
Explosion, cal/gm	876																														
Formation, cal/gm	-914																														

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Cyclotrimethylene Trinitrosamine

Preparation of Hexahydro-1,3,5-Trinitroso-s-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 isomyl 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 Duden and Scharff (Ann 288 (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-HEC 5742).

Destruction by Chemical Decomposition:

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

Cyclotrimethylene Trinitrosamine

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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 Trinitrosamine 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 Pratique" decreased from 125.5 to 123.5.
4. An Abel Test at 110°C gave no color to iodine starch paper in 15 minutes.

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

Cyclotrimethylene Trinitrosamine, %	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 Trinitrosamine
58% TNT

7,000

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Cyclotrimethylene TrinitrosamineReaction of Cyclotrimethylene Trinitrosamine 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)

Confinement	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:¹⁶

(a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.

(b) Louis Médard and Maurice Dutour, "Étude Des Propriétés De La Cyclotriméthylène Trinitrosamine," Mém 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 Trinitrosamine: 1174, 2179.

¹⁶See footnote 1, page 10.

DBX (Depth Bomb Explosive)

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Composition: % Ammonium Nitrate 21 RDX 21 TNT 40 Aluminum 18 C/H Ratio	Molecular Weight: 83	
	Oxygen Balance: CO ₂ % -46 CO % -26	
	Density: gm/cc	Cast 1.68
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 14	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ¹⁵ n _D ³⁰	
	Friction Pendulum Test: Steel Shoe Fiber Shoe	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 6.15 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 58.5	
	Explosion Temperature: °C Seconds, 0.1 (no cup used) 1 5 Ignites 400 10 15 20	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 146	
	Treuzl Test, % TNT:	
Flammability Index: Hygroscopicity: % Volatility:	Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.76 Brisance, % TNT 102	
	Detonation Rate: (c) Confinement None Condition Cast Charge Diameter, in. 1.6 Density, gm/cc 1.65 Rate, meters/second 6600	

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DBX (Depth Bomb Explosive)

Booster Sensitivity Test: (e)		Decomposition Equation:
Condition	Cast	Oxygen, atoms/sec
Tetryl, gm	100	(%/sec)
Wax, in. for 50% Detonation	1.35	Heat, kilocalorie/mole
Wax, gm		(ΔH , kcal/mol)
Density, gm/cc	1.76	Temperature Range, °C
		Phase
Heat of: (d)		Armor Plate Impact Test:
Combustion, cal/gm		
Explosion, cal/gm	1700	60 mm Mortar Projectile:
Gas Volume, cc/gm		50% Inert, Velocity, ft/sec
Formation, cal/gm		Aluminum Fineness
Fusion, cal/gm		
Specific Heat: cal/gm/°C (d)		500-lb General Purpose Bombs:
-5°C, density 1.75 gm/cc	0.25	
		Plate Thickness, inches
		1
		1¼
		1½
		1¾
Burning Rate:		
cm/sec		
Thermal Conductivity:		Bomb Drop Test:
cal/sec/cm/°C	13.2×10^{-4}	
Density 1.75 gm/cc		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:
Coefficient of Expansion:		
Linear, %/°C -73°C-75°C	4.5×10^{-5}	Max Safe Drop, ft
Volume, %/°C		
Hardness, Mohs' Scale:		500-lb General Purpose Bomb vs Concrete:
Young's Modulus: (d)		Height, ft
E', dynes/cm²	10.4×10^{10}	Trials
E, lb/inch²	1.51×10^6	Unaffected
Density, gm/cc	1.72	Low Order
		High Order
Compressive Strength: lb/inch² (d)	3210-3380	1000-lb General Purpose Bomb vs Concrete:
Density 1.78 gm/cc		
Vapor Pressure:		Height, ft
°C	mm Mercury	Trials
		Unaffected
		Low Order
		High Order

DBX (Depth Bomb Explosive)

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Color: Gray
Blast (Relative to TNT): (d) Air: Peak Pressure 118 Impulse 127 Energy 138 Air, Confined: Impulse Under Water: Peak Pressure -- Impulse -- Energy 136 Underground: Peak Pressure Impulse Energy	Principal Uses: Depth charge
	Method of Loading: Cast
	Loading Density: gm/cc 1.61-1.69
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
	Preparation: 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 19% of TNT previously melted at about 100 C.

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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:¹⁷

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

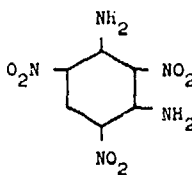
(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

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

¹⁷See footnote 1, page 10.

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

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Composition: % C 29.6 H 2.1 N 28.8 O 39.5 C/H Ratio 0.380		Molecular Weight: (C ₆ H ₅ N ₅ O ₆) 243
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 9		Oxygen Balance: CO ₂ % CO %
		Density: gm/cc Crystal 1.83
		Melting Point: °C (a) 290
		Freezing Point: °C
		Boiling Point: °C
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 46.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: 100
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.4 Explosion in 100 Hrs None		Trauzl Test, % TNT:
		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.65 Rate, meters/second 7500
Hygroscopicity: %		
Volatility:		

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

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-between;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 50,000 psi 1.65 Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Cook-Off Temperature: °C 320 Time, minutes 8 Heat of: Explosion, cal/gm 2876

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

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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 (97%), 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. Blankens 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 NH₃ 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-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schiepers (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-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 Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminobenzoic acid or 2,4,6-trinitro-3-aminophenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 32, 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).

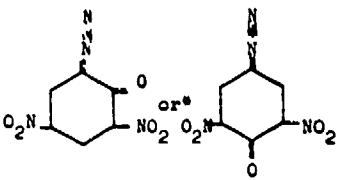
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3,3-Diamino-2,4,6-Trinitrobenzene (DATNB)

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 diaminotrinitro-benzene 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

AMCP 706-177

Composition: % C 34.3 H 0.9 N 26.7 O 38.1 C/H Ratio 1.056		Molecular Weight: (C ₆ H ₂ N ₄ O ₅) 210 Oxygen Balance: CO ₂ % -61 C.O % -15 Density: gm/cc Crystal 1.63 Melting Point: °C 157 Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4; (1 lb wt) 7 Sample Wt, mg 15		Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Detonates		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 7.6 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 47.5 Black powder, gms 45.6 Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 200 5 195 10 180 15 20		Ballistic Mortar, % TNT: (a) 97
73°C International Heat Test: % Loss in 48 Hrs		Treuzl Test, % TNT: Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs 2.10 % Loss, 2nd 48 Hrs 2.20 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 0.9 1.5 1.6 Rate, meters/second 4400 6600 6900
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.04		
Volatility: 50°C, 30 months Unaffected		

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2682, August 1949).

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Diazodinitrophenol

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

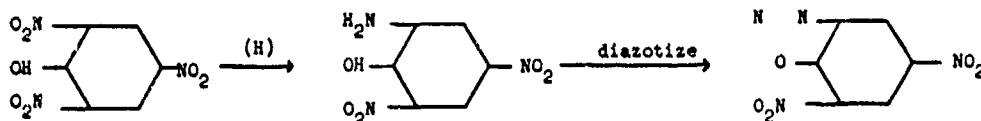
Diazodinitrophenol

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Solubility: gm/100 gm of the following substances: (c)

Solubility at 50°C

<u>Solvent</u>	<u>g</u>
Ethyl 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 Griess in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 663 (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 Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

¹⁸See footnote 1, page 10.

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DiazodinitrophenolElectrostatic 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:

<u>0</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>7</u>	<u>8</u>	<u>9</u>
150	13 ⁵²	34	355	827	318	2179
610		214			1838	
2120						

Diethylene Glycol Dinitrate (DEGN) Liquid

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Composition: % C 24.5 H 4.1 N 14.3 O 57.1 C/H Ratio 0.143		Molecular Weight: $(C_4H_8N_2O_7)$ 196 Oxygen Balance: CO ₂ % -41 CO % -8	
$ \begin{array}{c} H_2C - ONO_2 \\ \\ H_2C > O \\ \\ H_2C - ONO_2 \end{array} $		Density: gm/cc Liquid 1.38 Melting Point: °C 2 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg		Boiling Point: °C Decomposes 160 Refractive Index, n_D^{20} n_D^{20} 1.4498 n_D^{25}	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.3cc/20 hr/ga 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 42.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 237 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: 90 Treuzl Test, % TAT: 77	
100°C Heat Test: % Loss, 1st 48 Hrs 4.0 % Loss, 2nd 48 Hrs 3.0 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.38 Rate, meters/second 6760	
Hygroscopicity: %			
Volatility: 60°C, $\mu\text{g}/\text{cm}^2/\text{hr}$ 193			

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Diethylene Glycol Dinitrate (DEGN) Liquid

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2792 Explosion, cal/gm 841 Gas Volume, cc/gm 796 Formation, cal/gm 2020 Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 300-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: °C mm Mercury 20 0.0036 60 0.130	

Diethylene Glycol Dinitrate (DEGN) Liquid

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume: Hole Depth: Color: Colorless Principal Uses: Propellant compositions
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Loading 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	Storage: <div style="display: flex; justify-content: space-around;"> Method Liquid </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group Exudation Preparation: DEGN can be prepared with approximately 85% yield by adding diethyleneglycol to mixed acid (50% HNO ₃ , 45% H ₂ SO ₄ , and 5% H ₂ 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.
Viscosity, centipoises: Temp, 20°C 8.1	Hydrolysis, % Acid: 10 days at 22°C 0.003 5 days at 60°C 0.003 Solubility in Water, gm/100 gm, at: 25°C 0.40 60°C 0.60 Solubility, gm/100 gm, at 25°C, in: Ether 00 Alcohol 00 2:1 Ether:Alcohol 00 Acetone 00

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Diethylene Glycol Dinitrate (DEGN) LiquidOrigin:

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:¹⁹

See the following Picatinny Arsenal Technical Reports on DEGN:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>7</u>	<u>9</u>
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							

¹⁹See footnote 1, page 10.

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

AMCP 706-177

Composition: % C 31.6 H 3.2 N 14.7 O 50.5 C/H Ratio		Molecular Weight: $(C_{10}H_{12}N_4O_{12})$ 380	
$\begin{array}{c} \text{CHCO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \\ \\ \text{CHCO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \end{array}$		Oxygen Balance: CO ₂ % -59 CO % -17	
		Density: gm/cc Crystal 1.60	
		Melting Point: °C Form I 89 Form II 86	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 18		Boiling Point: °C	
		Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.66 120°C ---- 135°C 0.91 150°C	
Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected		250 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 4 Strokes 250 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Marker, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.49 Rate, mtc /second 6050	
Hygroscopicity: %			
Volatility:			

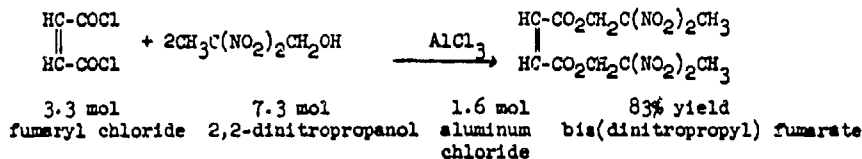
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Bis(2,2-Dinitropropyl) Fumarate (DNPF)

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: White
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses:
	Method of Loading: Cast
	Loading Density: gm/cc 1.50
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None
	Heat of: <div style="display: flex; justify-content: space-between;"> <div>Combustion, cal/gm</div> <div>3070 (calculated)</div> </div> <div style="display: flex; justify-content: space-between;"> <div>Detonation, cal/gm</div> <div>767 (calculated)</div> </div> Viscosity, poises: <div style="display: flex; justify-content: space-between;"> <div>Temp, 98.9°C</div> <div>0.586</div> </div> <div style="display: flex; justify-content: space-between;"> <div>106.5°C</div> <div>0.435</div> </div> Liquid Density, gm/cc: <div style="display: flex; justify-content: space-between;"> <div>Temp, 98.9°C</div> <div>1.382</div> </div> <div style="display: flex; justify-content: space-between;"> <div>106.5°C</div> <div>1.375</div> </div> Origin: Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

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 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: 20

- (a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.

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

²⁰ See footnote 1, page 10.

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

Composition: % C 31.4 H 3.7 N 14.7 O 50.2 C/H Ratio 0.250 $\begin{array}{c} \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \\ \\ \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \end{array}$	Molecular Weight: $(\text{C}_{10}\text{H}_{14}\text{N}_4\text{O}_{12})$ 382	
	Oxygen Balance: CO ₂ % -63 CO % -21	
	Density: gm/cc	Crystal 1.51
	Melting Point: °C 86	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_D^{20}	
	n_D^{20}	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.10 120°C 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 >400 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
	Troust Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

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

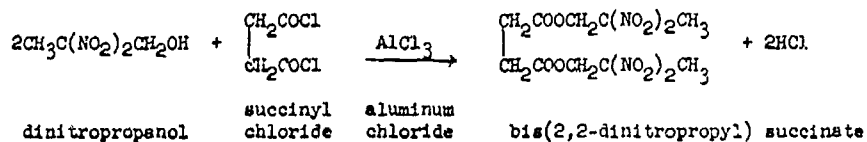
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Fragmentation Test: 90 mm HE, /471 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steril Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: White
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses:
	Method of Loading: Cast
	Loading Density: gm/cc
	Storage: Method Day Hazard Class (Quantity-Distance) Compatibility Group Exudation None
	Origin: 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:²¹

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

²¹See footnote 1, page 10.

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

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Composition: % C 23.6 H 2.5 N 19.7 O 54.2 C/H Ratio		Molecular Weight: (C ₇ H ₉ N ₅ O ₁₂)	355
		Oxygen Balance: CO ₂ % CO %	-29 +2.3
		Density: gm/cc	Crystal 1.68
		Melting Point: °C	Form I 11 Form II 95 Form III 59
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Freezing Point: °C	
		Boiling Point: °C	
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90 °C 100 °C 120 °C 135 °C 150 °C	--- 0.5
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		240 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 300 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetrayl	
75 °C International Heat Test: % Loss in 48 Hrs 100 °C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Ballistic Mixture, % TNT:	
		Trauzl Test, % TNT:	
		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	1.67 7600
Hygroscopicity: %			
Volatility:			

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

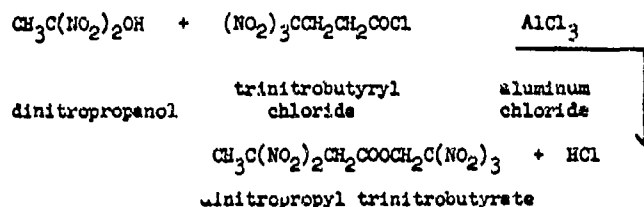
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glin's Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Method of Loading: Cast Loading Density: gm/cc 1.67
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Heat of: (c) <div style="display: flex; justify-content: space-between;"> Transition, cal/gm Solvent </div> <div style="display: flex; justify-content: space-between;"> CCl₄ DMF </div> I → III 6.2 4.8 II → I -16.6 -22.0 Heat of Solution, 30°C: <div style="display: flex; justify-content: space-between;"> Material ΔH Solution, cal/gm </div> <div style="display: flex; justify-content: space-between;"> CCl₄ DMF </div> Form III 29.5 8.1 Form I 35.6 12.8 Form II 19.1 -9.1 Origin: Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.

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

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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, chloroform-hexane, 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	0.075

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

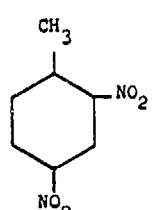
References:²²

- (a) M. E. Hill, Preparation and Properties of 2,2-Dinitropropanol Esters, NAVORD Report No. 2497, 3 July 1952.
- (b) W. B. Hewson, Hercules 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. 4427, 11 December 1956.

²²See footnote 1, page 10.

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2,4-Dinitrotoluene (DNT)

Composition: %			Molecular Weight: (C ₇ H ₅ N ₂ O ₄) 1.82	
C	46.3		Oxygen Balance: CO ₂ % -114 CO % - 53	
H	3.3		Density: gm/cc 1.521	
N	15.4		Melting Point: °C 71	
O	35.0		Freezing Point: °C	
C/H Ratio 0.579				
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg			Boiling Point: °C Decomposes 300	
			Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected			Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.04 135°C 150°C	
Rifle Bullet Impact Test: Trials			200 Gram Bomb Sand Test: Sand, gm 19.3	
Explosions 0				
Partials 0				
Burned 0				
Unaffected 100				
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 310 10 15 20			Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25	
75°C International Heat Test: % Loss in 48 Hrs			Ballistic Mortar, % TNT: (a) 71	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs			Treuzl Test, % TNT: (b) 64	
Flammability Index:			Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 25°C, 100% RH 0.00			Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:				

2,4-Dinitrotoluene (DNT)

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot W-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot I C-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Ingredient of propellant powder, dynamites and plastic explosives Method of Loading: Pressed, extruded or cast composition
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc Variable Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 1.2 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group Group D </div> Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	65.5°C KI Test: <div style="display: flex; justify-content: space-around;"> Minutes 60+ </div> Heat of: <div style="display: flex; justify-content: space-around;"> Combustion, cal/gm (b) 1545 </div> Thermal Conductivity: <div style="display: flex; justify-content: space-around;"> cal/sec/cm/°C Density 1.322 gm/cc 6.28 x 10⁻⁴ </div>

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2,4-Dinitrotoluene (DNT)Preparation:

See TNT.

Solubility: gm/100 gm of the following substances:

<u>30% Ethyl Alcohol</u>		<u>Nitroglycerin</u>		<u>Water</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</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, 1%:

<u>Solvent</u>	<u>%</u>	<u>Solvent</u>	<u>%</u>
CHCl ₃	65.076	C ₂ H ₅ OH (absolute)	3.039
CCl ₄	2.431	Ether (absolute)	9.422
C ₆ H ₆	60.644	Acetone	81.901
Toluol	45.470	Ethyl acetate	57.929
CH ₃ OH	5.014	CS ₂	2.306
C ₂ H ₅ 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: 23

(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) A. H. Blatt, 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	907	343	1044		1816	837	1538	249
	1781	1144	673	1084		1896			279
	1821	1672	1023	1094					779
	2031	1692	1663	1164					1749
	2221		1743	1324					
			2013	1464					
				1524					
				1674					
				1754					
				2094					

²³See footnote 1, page 10.

Dipentaerythritol Hexanitrate (DPEHN)

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Composition: % C 21.7 H 2.9 N 15.2 O 60.2		Molecular Weight: (C ₁₀ H ₁₆ N ₆ O ₁₉) 554	
$ \begin{array}{c} \text{ONO}_2 \qquad \text{ONO}_2 \\ \qquad \qquad \\ \text{CH}_2 \qquad \text{CH}_2 \\ \qquad \qquad \\ \text{ONO}_2 \text{OCH}_2 - \text{C} - \text{CH}_2 - \text{O} - \text{CH}_2 - \text{C} - \text{CH}_2 \text{ONO}_2 \\ \qquad \qquad \\ \text{CH}_2 \qquad \text{CH}_2 \\ \qquad \qquad \\ \text{ONO}_2 \qquad \text{ONO}_2 \end{array} $		Oxygen Balance: CO ₂ % -26 CO % + 3	
C/H Ratio 0.154		Density: gm/cc Crystal 1.63	
		Melting Point: °C 73.7	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 14 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 10		Boiling Point: °C	
		Refractive Index, n_D²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Unaffected		Vacuum Stability Test: c./40 Hrs, at 90°C 100°C 3.7 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 57.4	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 300 5 Explodes 255 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Mortar, % TNY: (a) 142	
		Treuzl Test, % TNT: (b) 128	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisacon, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.11 % Loss, 2nd 1/2 Hrs 0.10 Explosion in 100 Hrs None		Detonation Rate: (c) Confinement Copper tube Condition Pressed Charge Diameter, in. 0.39 Density, gm/cc 1.59 Rate, meters/second 7410	
Flammability Index:			
Hygroscopicity: % 0.03			
Volatility:			

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Dipentaerythritol Hexanitrate (DPEHN)

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, M42A1 Projectile, Lot KC 1: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Ingredient of priming compositions
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Method of Loading: Pressed Loading Density: gm/cc At 3000 to 4000 psi 1.59
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation Preparation: (Chemistry of Powder and Explosives, Davis) $2(\text{HO-CH}_2)_4\text{C} \xrightarrow{\text{Dehydration}} (\text{HO-CH}_2)_3\text{C-O-C}(\text{CH}_2\text{-OH})_3 \longrightarrow (\text{O}_2\text{NO-CH}_2)_3\text{C-O-C}(\text{CH}_2\text{-ONO}_2)_3$ Dipentaerythritol Hexanitrate is procured in the pure state (melting point 72°C) by fractional crystallization of crude PETN from moist acetone. Origin: Formed as an impurity in the preparation of PETN. 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)). Heat of: Combustion, cal/gm 2260

Dipentaerythritol Hexanitrate (DPEHN)

AKCP 706-177

References:²⁴

- (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) 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. 218-203.
- (d) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.

²⁴See footnote 1, page 10.

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Dynamite, Low Velocity, Picatinny Arsenal (LVD)

Composition: 99.5/0.5 RDX/1-MA dye* 17.5 % TNT 67.8 Triphenylethyrol 8.6 68/32 Vistac No 1/DOS binders** 4.1 Cellulose acetate, LH-1 2.0 *RDX, Class E; 1-MA is 96% pure 1-methylamino-anthraquinone. **Vistac No 1 is low MW polybutene; DOS is dioctylsebacate. C/H Ratio		Molecular Weight:	
		Oxygen Balance: CO, % CO %	
		Density: gm/cc	Loading 0.9
		Melting Point: °C	
		Freezing Point: °C	
		Boiling Point: °C	
		Refractive Index: n_D^{20} n_D^{25} n_D^{30}	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 22 Sample Wt, mg 19		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.40 135°C 150°C	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		200 Gram Bomb Sand Test: Sand, gm 40.5	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.15	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 480 10 15 20		Ballistic Mortar, % TNT: 92	
75°C International Heat Test: % Loss in 48 Hrs		Trawl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement None Condition Hand tamped Charge Diameter, in. 1.25 Density, gm/cc 0.9 Rate, meters/second 4377; or 14400 ft/sec	
Hygroscopicity: % 71°C, 95% RH, 30 days 0.31 Satisfactory			
Volatility:			

Dynamite, Low Velocity, Picatinny Arsenal (LVD)

AMCP 706-177

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Pink Principal Uses: Excavation, demolition, and cratering Method of Loading: Ball Packer machine loaded
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 0.9 Tamped cartridge 1-1/2" diameter, 8" long
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	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 Positive Air Gap Propagation: Max distance will, inch 2-1/2 min distance will not, inch 3 Stick Water Immersion: Weight gain, % 9-16 Heat of: Explosion, cal/gm 625 Gas Volume, cc/gm 611 Cold Storage: Plastic to -65°F Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory

AMCP 706-177

Dynamite, Low Velocity, Picatinny Arsenal (LVD)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: 25

(a) H. W. Voigt, 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:

<u>0</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1260	1381	782	864	1285	1416	507	848	1819
1360	1611	1532	1464		1436	957	1828	
1720					1506			
1760					2056			

²⁵See footnote 1, page 10.

Dynamite, Medium Velocity, Hercules (MVD)

AMCP 706-177

Composition: %		Molecular Weight:	
RDX	75	Oxygen Balance:	
TNT	15	CO ₂ %	-51
Starch	5	CO %	
SAE No. 10 Oil	4	Density: gm/cc	
Vistanex oil gel*	1	Loading	1.1
*80/15/5, SAE No. 10 weight oil/Vistanex B-120XC/Navy D2 wax. C/H Ratio		Melting Point: °C	
Impact Sensitivity, 2 Kg Wt:		Freezing Point: °C	
Bureau of Mines Apparatus, cm'	>100	Nitroglycerin Equivalent, %	
Sample Wt 20 mg	18	Refractive Index, n_D²⁰	
Picatinny Arsenal Apparatus, in.	25	n _D ²⁰	
Sample Wt, mg		n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Crackles	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test:		100°C	0.80
	Trials	120°C	0.94
Explosions	%	135°C	
Partial	0	150°C	
Burned	10	200 Gram Bomb Sand Test:	
Unaffected	90	Sand, gm	52.6
Explosion Temperature:		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	°C	Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5		Lead Azide	0.20
10		Tetryl	0.10
15		Ballistic Mortar, % TNT:	
20		122	
75°C International Heat Test:		Trauzl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test:	
100°C Heat Test:		Method	
% Loss, 1st 48 Hrs	0.62	Condition	
% Loss, 2nd 48 Hrs	0.12	Confined	
Explosion in 100 Hrs	None	Density, gm/cc	
Flammability Index:		Brisance, % TNT	
Hygroscopicity: %		Detonation Rate:	
71°C, 95% RH, 30 days	Satisfactory	Confinement	None
Volatility:		Condition	Machine tamped
		Charge Diameter, in.	1.50
		Density, gm/cc	1.1
		Rate, meters/second 6000-6100; or 20,000 ft/sec	

AMCP 706-177

Dynamite, Medium Velocity, Hercules (MVD)

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Buff Principal Uses: Excavation, demolition, and cratering Method of Loading: Hall Packer machine loaded
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Loading Density: gm/cc 1.1 Cartridge 1-1/2" diameter, 8" long Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group Group A </div> Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	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 crimper Satisfactory

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

²⁶See footnote 1, page 10.

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EC Blank Fire

Composition: % Nitrocellulose, 13.25% N 80 Barium Nitrate 8 Potassium Nitrate 8 Starch 3 Diphenylamine 0.75 Aurine 0.25 C/H Ratio	Molecular Weight: Approximately 503	
	Oxygen Balance: CO ₂ % +5 CO % -25	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 19 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
	Friction Pendulum Test: Steel Shoe Snaps Fiber Shoe	
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	
	200 Gram Bomb Sand Test: Sand, gm 46.8	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 200 10 15 20	
75°C International Heat Test: % Loss in 48 Hrs 1.8 100°C Heat Test: % Loss, 1st 48 Hrs 2.0 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22 Lead Azide Tetryl :	
	Ballistic Mortar, % TNT:	
	Treuxl Test, % TNT:	
Flammability Index: Hygroscopicity: % 30°C, 70% RH 6.2 Volatility:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

EC Blank Fire

AMCP 706-177

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth								
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:								
Blact (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Grenades; caliber .30 blank								
References: ²⁷ (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.	<div> Method of Loading: Loose </div> <div> Loading Density: gm/cc 0.40 </div> <div> Storage: <div> Method Wet </div> <div> Hazard Class (Quantity-Distance) Class O </div> <div> Compatibility Group Group J </div> <div> Exudation </div> </div> <div> Preparation: 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. </div> <div> Origin: Invented in 1882 as bulk sporting (smokeless) powder by W. F. Reid and D. Johnson at the Explosive Company (whence the name "EC") in England (British Patent 619). </div> <div> 120°C Heat Test: <table> <tr> <td></td> <td><u>Minutes</u></td> </tr> <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> </table> </div>		<u>Minutes</u>	Salmon Pink	150	Red Fumes	300+	Explodes	300+
	<u>Minutes</u>								
Salmon Pink	150								
Red Fumes	300+								
Explodes	300+								

²⁷See footnote 1, page 10.

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Ednatol, 55/45

Composition:		Molecular Weight:	
%		178	
Haleite (Ethylene Dinitramine) 55		Oxygen Balance:	
TNT 45		CO ₂ % -51	
		CO % -17	
		Density: gm/cc	Cast 1.62
		Melting Point: °C	Eutectic 80
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm 95		Refractive Index, n_D²⁰	
Sample Wt 20 mg		n _D ²⁵	
Picotinn: Arsenal Apparatus, in. 20		n _D ³⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe Unaffected		cc/40 Hrs, at 90°C	
Fiber Shoe Unaffected		100°C 1.0	
Rifle Bullet Impact Test:		120°C 11+	
Trials		135°C	
%		150°C	
Explosions 0		200 Gram Bomb Sand Test:	
Partials 0		Sand, gm	49.4
Burned 7		Sensitivity to Initiation:	
Unaffected 93		Minimum Detonating Charge, gm	
Explosion Temperature: *		Mercury Fulminate 0.02*	
Seconds, 0.1 (no cap used) 435		Lead Azide 0.26*	
1 248		Tetryl	
5 Decomposes 190		*Alternative initiating charges.	
10 183		Ballistic Mortar, % TNT: (a)	
15 176		119	
20 168		Tread Test, % TNT: (b)	
*Composition Haleite/TNT, 60/40.		120	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		52/48	
100°C Heat Test:		Method B	
% Loss, 1st 48 Hrs 0.2		Condition Cast	
% Loss, 2nd 48 Hrs 0.1		Confined No	
Explosion in 100 Hrs None		Density, gm/cc 1.62	
Flammability Index: Will not continue to burn		Brisance, % TNT 112	
Hygroscopicity: % None		Detonation Rate:	
Volatility:		Confinement None	
		Condition Cast	
		Charge Diameter, in. 1.0	
		Density, gm/cc 1.63	
		Rate, meters/second 7340	

Ednatol, 55/45

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Fragment Test:			Shaped Charge Effectiveness, TNT = 100: <u>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
Total No. of Fragments:			Color: Yellow	
For TNT	703	703	Principal Uses: Projectiles, bombs; special ammunition components	
For Subject HE	842	902		
3 inch HE, M42A1 Projectile, Lot KC-3:			Method of Loading: Cast	
Density, gm/cc		1.60	Loading Density: gm/cc 1.65	
Charge Wt, lb		0.845		
Total No. of Fragments:			Storage:	
For TNT		514		
For Subject HE		536	Method: Dry	
Fragment Velocity: ft/sec			Hazard Class (Quantity-Distance) Class 9	
At 9 ft		2730	Compatibility Group Group I	
At 25½ ft		2430	Exudation Does not exude at 65°C	
Density, gm/cc		1.62	Eutectic Temperature, °C: 79.8	
Blast (Relative to TNT): (d, e)			gm Heleite/100 gm TNT 79.8°C 0.48	
Air:			95.0°C 1.12	
Peak Pressure		108	Compatibility with Metals:	
Impulse		110	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.	
Energy		108	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.	
Air, Confined:				
Impulse		--		
Under Water:				
Peak Pressure		--		
Impulse		--		
Energy		113		
Underground:				
Peak Pressure				
Impulse				
Energy				
Booster Sensitivity Tests: (d)				
Condition		Cast		
Tetryl, gm		100		
Wax, in. for 50% Detonation		1.28		
Density, gm/cc		1.62		

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Ednatol, 55/45Preparation:

Wet Haleite is added slowly to molten 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 (EINA) and TNT, designated Ednatol, were developed at Picatinny Arsenal just prior to World War II.

References: 28

(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 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 Teteryl 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 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:

<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>
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		

²⁸See footnote 1, page 10.

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

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Composition: % C 25.6 H 2.6 N 17.1 O 54.7 C/H Ratio 0.235	Molecular Weight: ($C_{10}H_{12}N_6O_{16}$) 468	
	Oxygen Balance: CO ₂ % -34 CO % 0	
	Density: gm/cc Crystal 1.63	
	Melting Point: °C 96	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
	Friction Pendulum Test: Steel Shoe Fiber Shoe	
Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
	20% Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point 230 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Marker, % TNT:	
	Tensile Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.63 Rate, meters/second 7340	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

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Ethylene Glycol Di-Trinitrobutyrate (GTNB)

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color:									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Casting medium for HE compounds									
	Method of Loading: Cast									
	Loading Density: gm/cc 1.60									
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None									
	Preparation: (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. Origin: First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey. Viscosity, poises: <table> <tr> <td>Temp, 98.9°C</td> <td>0.246</td> </tr> <tr> <td>106.5°C</td> <td>0.193</td> </tr> </table> Liquid Density, gm/cc: <table> <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:²⁹

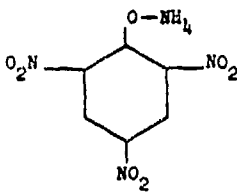
(a) U. S. Rubber Company Progress Report No. 14, Navy Contract NOrd-10129, 1 February 1951 to 1 May 1951.

(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. 02894).

²⁹See footnote 1, page 10.

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Explosive D (Ammonium Picrate)

Composition: % C 29.3 H 2.4 N 22.7 O 45.6 C/H Ratio 0.317		Molecular Weight: (C ₆ H ₆ N ₄ O ₇) 246 Oxygen Balance: CO ₂ % -52 CO % -13	
		Density: gm/cc Crystal 1.72 Melting Point: °C Decomposes 265 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 18		Boiling Point: °C Refractive Index, n_D²⁰: a _D 1.508 b _D 1.870 c _D 1.907	
Friction and Slump Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.4 135°C 150°C 0.4	
Rifle Bullet Impact Test: Trials Explosions 0 Partials 0 Burned 30 Unaffected 70		200 Gram Bomb Sand Test: Sand, gm 39.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 405 1 367 5 Decomposes 318 10 314 15 299 20 295		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.06	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: (a) 99	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None		Yezzi Test, % TNT: Plate Dent Test: Method A Condition Pressed Cased Yes Density, gm/cc 1.50 Brisance, % TNT 91	
Permeability Index:		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.55 Rate, meters/second 6850	
Hygroscopicity: % 100% RH 0.1			
Volatility:			

Explosive D (Ammonium Picrate)

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.50 Charge Wt, lb 1.94 Total No. of Fragments: For TNT 703 For Subject HE 649 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.55 Charge Wt, lb 0.82 Total No. of Fragments: For TNT 514 For Subject HE 508	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow-orange Principal Uses: AP projectiles and bombs Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc psi x 10³ <div style="display: flex; justify-content: space-around;"> 3510121520 </div> <div style="display: flex; justify-content: space-around;"> 1.331.411.471.491.511.53 </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C Sensitivity to Electrostatic Discharge, Joules: (d) <u>Through 100 Mesh:</u> Confined 6.0 Unconfined 0.025 Booster Sensitivity Test: (c) Condition Pressed Tetryl, gm 100 Wax, in. for 50% Detonation 1.27 Density, gm/cc 1.54 Heat of: Combustion, cal/gm 2890 Explosion, cal/gm 800 Formation, cal/gm 395

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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:

		<u>Minimum Detonating Charge</u>		
<u>Years</u>	<u>Storage °C</u>	<u>Mercury Fulminate (gm)</u>	<u>Tetryl (gm)</u>	<u>Sand Crushed (gm)</u>
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 (%), of: (a)

<u>Water</u>		<u>Alcohol</u>		<u>Ethyl Acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	1.1	0	0.515	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:³⁰

(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 1943.

³⁰See footnote 1, page 10.

Explosive D (Ammonium Picrate)

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- (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) 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	1651	582		704	425	556	1797	838	1759
1380		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

Composition: % C 24.1 H 3.0 N 14.1 O 58.8 C/H Ratio 0.180		Molecular Weight: (C ₆ H ₉ N ₃ O ₁₁) 299 Oxygen Balance: CO ₂ % -30 CO % 3	
$ \begin{array}{c} \text{O} \quad \text{ONO}_2 \\ \parallel \quad \\ \text{CH}_2 - \text{O} - \text{C} - \text{CH} - \text{CH}_3 \\ \quad \quad \\ \text{CH} - \text{ONO}_2 \\ \\ \text{CH}_2 - \text{ONO}_2 \end{array} $		Density: gm/cc Liquid 1.47 Melting Point: °C Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 (1 lb wt); 42 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C Refractive Index, n_D²⁰: n _D ²⁰ 1.44 n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 5.9 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 13.1	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 223 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: %			
Volatility: 60°C, mg/cm ² /hr 28			

Glycerol Monolactate Trinitrate (GLTN) Liquid

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Gelatinizer for nitrocellulose Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Liquid </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Hydrolysis, % Acid: <div style="display: flex; justify-content: space-around;"> <div>10 days at 22°C</div> <div>0.021</div> </div> <div style="display: flex; justify-content: space-around;"> <div>5 days at 60°C</div> <div>0.014</div> </div> Solubility in Water, <u>gm/100 gm, at:</u> <div style="display: flex; justify-content: space-around;"> <div>25°C</div> <div><0.01</div> </div> <div style="display: flex; justify-content: space-around;"> <div>60°C</div> <div><0.015</div> </div> Solubility, gm/100 gm, <u>at 25°C, in:</u> <div style="display: flex; justify-content: space-around;"> <div>Ether</div> <div>-</div> </div> <div style="display: flex; justify-content: space-around;"> <div>2:1 Ether:Alcohol</div> <div>-</div> </div> <div style="display: flex; justify-content: space-around;"> <div>Acetone</div> <div>-</div> </div> Heat of: <div style="display: flex; justify-content: space-around;"> <div>Combustion, cal./gm</div> <div>2407</div> </div>

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Glycerol Monolactate Trinitrate (GLTN) LiquidPreparation:

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 HNO₃/H₂SO₄ 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).

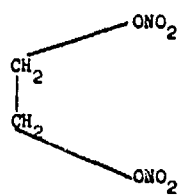
Reference:³¹

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

³¹See footnote 1, page 10.

Glycol Dinitrate (GDN) Liquid

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Composition: % C 15.8 H 2.6 N 18.4 O 63.2 C/H Ratio 0.092		Molecular Weight: ($C_2H_4N_2O_6$) 152 Oxygen Balance: CO ₂ % 0.0 CO % 21	
		Density: gm/cc Liquid, 25°C 1.48 Melting Point: °C -20 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 4 (1 lb wt); 56 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C Refractive Index, n_D^{20} n_D^{20} 1.4452 n_D^{20}	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 257 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Treuzl Test, % TNT:	
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 30°C, 90% RH 0.00		Detonation Rate: Confinement Glass tube Condition Liquid Charge Diameter, in. 10 Density, gm/cc 1.485 Rate, meters/second 7300 and 2050	
Volatility:			

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Glycol Dinitrate (GN) Liquid

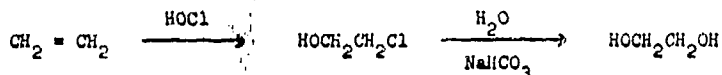
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth																						
Fragment Velocity: ft/sec: At 9 ft At 25½ ft Density, gm/cc	Color: Yellow Principal Uses: Ingredient of nonfreezing dynamite																						
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Loading Density: gm/cc Storage: <div style="display: flex; justify-content: space-around;"> Method Liquid </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group Exudation																						
	Solubility in 1000 cc Water: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>Temp., °C</u></th><th style="text-align: center;"><u>Grams</u></th></tr> </thead> <tbody> <tr><td style="text-align: center;">15</td><td style="text-align: center;">6.2</td></tr> <tr><td style="text-align: center;">20</td><td style="text-align: center;">6.8</td></tr> <tr><td style="text-align: center;">50</td><td style="text-align: center;">9.2</td></tr> </tbody> </table> Viscosity, centipoises: <div style="display: flex; justify-content: space-between;"> Temp. 20°C 4.2 </div> Vapor Pressure: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"><u>°C</u></th><th style="text-align: center;"><u>mm Mercury</u></th></tr> </thead> <tbody> <tr><td style="text-align: center;">0</td><td style="text-align: center;">0.0044</td></tr> <tr><td style="text-align: center;">20</td><td style="text-align: center;">0.038</td></tr> <tr><td style="text-align: center;">40</td><td style="text-align: center;">0.26</td></tr> <tr><td style="text-align: center;">60</td><td style="text-align: center;">1.3</td></tr> <tr><td style="text-align: center;">80</td><td style="text-align: center;">5.9</td></tr> <tr><td style="text-align: center;">100</td><td style="text-align: center;">22.0</td></tr> </tbody> </table> Heat of: <div style="display: flex; justify-content: space-between;"> Combustion, cal/gm 1764 </div> <div style="display: flex; justify-content: space-between;"> Formation, cal/gm (b) 366 </div>	<u>Temp., °C</u>	<u>Grams</u>	15	6.2	20	6.8	50	9.2	<u>°C</u>	<u>mm Mercury</u>	0	0.0044	20	0.038	40	0.26	60	1.3	80	5.9	100	22.0
<u>Temp., °C</u>	<u>Grams</u>																						
15	6.2																						
20	6.8																						
50	9.2																						
<u>°C</u>	<u>mm Mercury</u>																						
0	0.0044																						
20	0.038																						
40	0.26																						
60	1.3																						
80	5.9																						
100	22.0																						

Glycol Dinitrate (GDN) Liquid

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Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitioglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$, 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 (Mém poudr 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

References: ³²

- (a) Ph. Naoum, 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.

³²See footnote 1, page 10.

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Composition:		Molecular Weight:	
%		93	
RDX	45	Oxygen Balance:	
TNT	30	CO ₂ %	
Aluminum	20	CO %	
D-2 Wax	5	Density: gm/cc	
Calcium Chloride, added	0.5	Cast 1.74	
C/H Ratio		Melting Point: °C	
Impact Sensitivity, 2 Kg Wt:		Freezing Point: °C	
Bureau of Mines Apparatus, cm --		Boiling Point: °C	
Sample Wt 20 mg		Refractive Index, n_D²⁰	
Picatinny Arsenal Apparatus, in. (c) 14		n _D ¹⁵	
Sample Wt, mg 18		n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe Unaffected		cc/40 Hrs, at	
Fiber Shoe ---		90°C	
Rifle Bullet Impact Test:		100°C	
Trials (b)		120°C	
%		135°C	
Explosions 80		150°C	
Partials --		200 Gram Bomb Sand Test:	
Burned --		Sand, gm	
Unaffected 20		49.5	
Explosion Temperature: °C (a)		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used) ---		Minimum Detonating Charge, gm	
1 ---		Mercury Fulminate	
5 610(min) (c)		Lead Azide	
10		Tetryl	
15		Ballistic Mortar, % TNT: (d)	
20		135	
75°C International Heat Test:		Treuzl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test:	
100°C Heat Test:		Method	
% Loss, 1st 48 Hrs 0.78		Condition	
% Loss, 2nd 48 Hrs 0.00		Confined	
Explosion in 100 Hrs None		Density, gm/cc	
Flammability Index:		Brisance, % TNT	
Hygroscopicity: %		Detonation Ratio:	
30°C, 95% RH, 7 days 2.01		(a, b)	
71°C, 95% RH, 7 days 1.77		Confinement	
Volatility:		Condition	
		Cast	
		Charge Diameter, in.	
		1.0	
		Density, gm/cc	
		1.71	
		Rate, meters/second	
		7191	

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Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3972 Explosion, cal/gm 923 Gas Volume, cc/gm 733 Formation, cal/gm Fusion, cal/gm 78°C (b) 10.25	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) 30°C 0.269 50°C 0.268	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C 35°C (b) 1.10×10^{-3}	
Coefficient of Expansion: Linear, ΔL /inch 0°C 40×10^{-4} 35°C 83×10^{-4} 70°C 131×10^{-4}	
Hardness, Mohs' Scale: Young's Modulus: (b) E', dynes/cm ² 9.0×10^9 E, lb/inch ² 1.30×10^5 Density, gm/cc 1.71	
Compressive Strength: lb/inch ² See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch ² 1083 Density, gm/cc 1.71 Ultimate deformation, % 1.32	

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Fragmentation Test: (b) 90 mm HE, M71 Projectile, Lot EGS-1-17: Density, gm/cc Charge Wt, lb Total No. of Fragments: For Composition B 998 For Subject HE 714 For 80/20 Tritonal 616 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table> Color: Gray Principal Uses: HE charge Method of Loading: Cast Loading Density: gm/cc 1.71		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None									
Blast (Relative to TNT): (a) Air: 3.25" diameter sphere Peak Pressure Δ psi Catenary 25.4 Impulse IFOC Pendulum 19.8 Energy ---- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy										

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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</u> m/s	<u>Unconfined</u> m/s	<u>Confined</u> m/s	<u>Unconfined</u> m/s
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
H-6, density, gm/cc 1.69	Ground	7190	7360	7340	6370
	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</u> m/s	<u>30,000</u> m/s	<u>60,000</u> m/s	<u>90,000</u> m/s
TNT, density, gm/cc 1.51	1	2940	2991	3119	2868
	2	3523	4191	5077	4980
H-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".

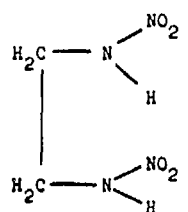
References:

See HBX-1; HBX-3 reference list.

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Haleite (Ethylene Dinitramine) (EDNA)

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

Composition: % C 16.0 H 4.0 N 37.3 O 42.7 C/H Ratio 0.066		Molecular Weight: $(C_2H_6N_4O_4)$ 150	
		Oxygen Balance: CO ₂ % -32 CO % -10.5	
		Density, m/cc Crystal 1.71	
		Melting Point: °C Decomposes 175+	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 48 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 17		Boiling Point: °C	
		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.5 120°C 1.5 135°C -- 150°C 11+	
Rifle Bullet Impact Test: Trials Explosions 0 Partial 60 Burned 20 Unaffected 20		200 Gram Bomb Sand Test: Sand, gm 52.3	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 265 1 216 5 Decomposes 189 10 178 15 173 20 170		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.21 Lead Azide 0.13 Tetryl --	
		Ballistic Mortar, % TNT: (a) 139	
		Trawl Test, % TNT: (b) 122	
75°C International Heat Test: % Loss in 48 Hrs 0.01		Plate Dent Test: (c) Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 122	
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.3 Explosion in 100 Hrs None		Detonation Rate: Confinement Unconfined Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.49 Rate, meters/second 7570	
Flammability Index: 138			
Hygroscopicity: % 0.01			
Volatility: Nil			

Haleite (Ethylene Dinitramine) (EDNA)

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Booster Sensitivity Test:		Decomposition Equation: (e)		
Condition	(d) Pressed	Oxygen, atoms/sec	$10^{12.8}$	$10^{12.1}$
Tetryl, gm	100	(Z/sec)		$10^{11.1}$
Wax, in. for 50% Detonation	2.09	Heat, kilocalorie/mole	30.5	37.3
Wax, gm		(ΔH , kcal/mol)		30.8
Density, gm/cc	1.42	Temperature Range, °C	184-254	-- 144-164
		Phase	Liquid	Solid Solid
Heat of:		Armor Plate Impact Test:		
Combustion, cal/gm	2477	60 mm Mortar Projectile:		
Explosion, cal/gm	1276	50% Inert, Velocity, ft/sec		
Gas Volume, cc/gm	900	Aluminum Fineness		
Formation, cal/gm	134	500-lb General Purpose Bombs:		
Fusion, cal/gm		Plate Thickness, inches		
Specific Heat: cal/gm/°C		1		
Burning Rate:		1 1/4		
cm/sec		1 1/2		
Thermal Conductivity:		1 1/2		
cal/sec/cm/°C		1 3/4		
Coefficient of Expansion:		Bomb Drop Test:		
Linear, %/°C		T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:		
Volume, %/°C		Max Safe Drop, ft		
Hardness, Mohs' Scale:		500-lb General Purpose Bomb vs Concrete:		
Young's Modulus:		Height, ft		
E', dynes/cm ²		Trials		
E, lb/inch ²		Unaffected		
Density, gm/cc		Low Order		
Compressive Strength: lb/inch²		High Order		
Vapor Pressure:		1000-lb General Purpose Bomb vs Concrete:		
°C	mm Mercury	Height, ft		
		Trials		
		Unaffected		
		Low Order		
		High Order		

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Haleite (Ethylenedinitramine) (EDNA)

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb -- Total No. of Fragments: For TNT -- For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: <u>95/5 Haleite/vax</u> Density, gm/cc 1.56 Charge Wt, lb -- Total No. of Fragments: For TNT 514 For Subject HE 600	Shaped Charge Effectiveness, TNT = 100: <div style="text-align: center;">Glass Cones Steel Cones</div> Hole Volume Hole Depth Color: White Principal Uses: Booster Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc psi x 10³ <div style="display: flex; justify-content: space-around;"> <div>5 1.28</div> <div>10 1.38</div> <div>12 1.41</div> <div>15 1.44</div> <div>20 1.49</div> </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Exudation None

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:

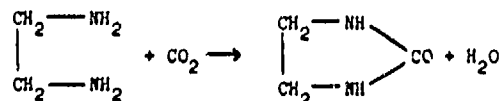
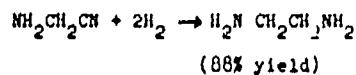
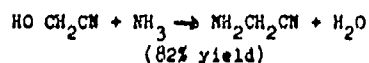
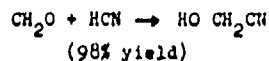
<u>Habit</u>	<u>cm</u>
1st plate	55
2nd plate	55
Bi-pyramid	71
Bracydome	66
Sphenoid	46

Solubility: gm/100 gm (%) of:

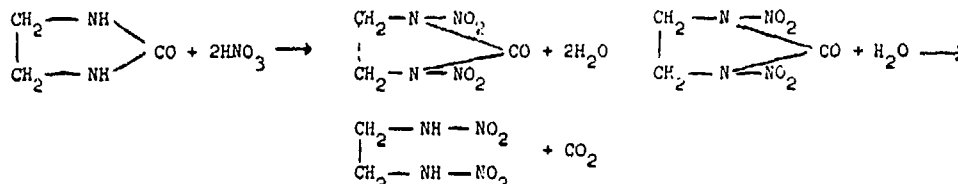
<u>Water</u>		<u>Alcohol</u>	
<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</u>
20	0.25	20	1.00
40	0.75	40	2.46
60	2.13	60	5.29
80	6.38	78	10.4
100	>20		

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 520 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.

Ethyleneurea is very easily nitrated, with strong nitric acid (95%). At ordinary temperature, and in a very short time, and the dinitroethyleneurea 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 Klobbie (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: 33

- (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 RFX/Wax Mixtures as a Substitute for Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) R. J. Finkelstein and G. Gamov, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (f) M. A. Cook and M. Taylor Abbe, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

33See footnote 1, page 10.

Haleite (Ethylene Dinitramine) (EDNA)

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(g) 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

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HBX-1

Composition:		Molecular Weight:		102
% RDX		Oxygen Balance:		
TNT		CO ₂ %		-68
Aluminum		CO %		-35
D-2 Wax		Density: gm/cc		Cast 1.72
Calcium Chloride, added		Melting Point: °C		
C/H Ratio		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C		
Bureau of Mines Apparatus, cm		Refractive Index, n_D²⁰		
Sample Wt 20 mg		n _D ²⁰		
Picatinny Arsenal Apparatus, in.		n _D ²⁰		
Sample Wt, mg				
Friction Pendulum Test: (b)		Vacuum Stability Test:		(a, b)
Steel Shoe		cc/40 Hrs, at		
Fiber Shoe		90°C		----
		100°C		0.47
Rifle Bullet Impact Test:		120°C		0.98
Trials (b)		135°C		----
% Explosions		150°C		11+
73		200 Gram Bomb Sand Test:		
Partial		Sand, gm		48.1
Burned				
Unaffected				
Explosion Temperature: °C (a)		Sensitivity to Initiation:		
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm		
1		Mercury Fulminate		----
5		Lead Azide		0.20
10		Tetryl		0.10
15		Ballistic Mortar, % TNT:		(a) 133
20		Trawl Test, % TNT:		
75°C International Heat Test:		Plate Dant Test:		
% Loss in 48 Hrs		Method		
100°C Heat Test:		Condition		
(b)		Confined		
% Loss, 1st 48 Hrs		Density, gm/cc		
0.058		Brisance, % TNT		
% Loss, 2nd 48 Hrs		Detonation Rate:		(a, b)
Explosion in 100 Hrs		Confinement		None
None		Condition		Cast
Flammability Index:		Charge Diameter, in.		1.0
Hygroscopicity:		Density, gm/cc		1.69
% 30°C, 95% RH, 7 days		Rate, meters/second		7224
2.98				
% 71°C, 95% RH, 7 days				
1.13				
Volatility:				

HBX-1

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Booster Sensitivity Test: Condition (c) Cast Tetrayl, gm 100 Wax, in. for 50% Detonation 1.25 Wax, gm Density, gm/cc 1.73		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase	
Heat of: Combustion, cal/gm (b) 3802 Explosion, cal/gm 919 Gas Volume, cc/gm Formation, cal/gm 758 Fusion, cal/gm 78°C 9.25		Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4	
Specific Heat: cal/gm/°C (b) 30°C 0.249 50°C 0.261		Bomb Drop Test: 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	
Burning Rate: cm/sec			
Thermal Conductivity: cal/sec/cm/°C 35°C (b) 0.97×10^{-3}			
Coefficient of Expansion: (b) Linear, $\Delta L/\Delta \text{inch}$ 0°C 46×10^{-4} 35°C 95×10^{-4} 70°C 159×10^{-4}			
Hardness, Mohs' Scale:			
Young's Modulus: (b) E', dynes/cm ² 10.3×10^9 E, lb/inch ² 1.49×10^{-5} Density, gm/cc 1.69			
Compressive Strength: lb/inch ² See below			
Vapor Pressure: °C mm Mercury (b) Compressive Strength: lb/inch ² 1303 Density, gm/cc 1.69 Ultimate deformation, % 1.38			

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HBX-1

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

HBX-3

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Composition:		Molecular Weight:	
%		64	
RDX	31	Oxygen Balance:	
TNT	29	CO ₂ %	
Aluminum	35	CO %	
D-2 Wax	5	Density: gm/cc	
Calcium Chloride, added	0.5	Cast	
C/H Ratio		1.84	
Impact Sensitivity, 2 Kg Wt:		Melting Point: °C	
Bureau of Mines Apparatus, cm	--	Freezing Point: °C	
Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.	15	Refractive Index, n_D²⁰	
Sample Wt, mg	23	n _D ²⁵	
Friction Pendulum Test:		Refractive Index, n_D³⁰	
Steel Shoe	Unaffected	Vacuum Stability Test:	
Fiber Shoe	---	(a, b)	
Rifle Bullet Impact Test:		cc/40 Hrs, at	
	Trials (b)	90°C	
	%	100°C	
Explosions	78	120°C	
Partials	--	135°C	
Burned	--	150°C	
Unaffected	22	200 Gram Bomb Sand Test:	
Explosion Temperature: °C (a)		Sand, gm	
Seconds, 0.1 (no cap used)	---	(b)	
1	---	44.9	
5	500	Sensitivity to Initiation:	
10		Minimum Detonating Charge, gm	
15		Mercury Fulminate	
20		Lead Azide	
75°C International Heat Test:		Tetryl	
% Loss in 48 Hrs		Ballistic Mortar, % TNT:	
100°C Heat Test:		(d)	
(b)		Treuxl Test, % TNT:	
% Loss, 1st 48 Hrs		Flate Dent Test:	
% Loss, 2nd 48 Hrs		Method	
Explosion in 100 Hrs		Condition	
None		Confined	
Flammability Index:		Density, gm/cc	
Hygroscopicity: %		Brisance, % TNT	
30°C, 95% RH, 7 days		Detonation Rate:	
(b)		(a, b)	
71°C, 95% RH, 7 days		Confinement	
2.01		Condition	
Volatility:		Cast	
		Charge Diameter, in.	
		1.0	
		Density, gm/cc	
		1.81	
		Rate, meters/second	
		6917	

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HBX-3

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase	
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm		Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4	
Specific Heat: cal/gm/°C 30°C 50°C		0.254 0.254	
Burning Rate: cm/sec		Bomb Drop Test: 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	
Thermal Conductivity: cal/sec/cm/°C 35°C		(b) 1.70×10^{-3}	
Coefficient of Expansion: Linear, ΔL /inch 0°C 35°C 70°C		(b) 4.0×10^{-4} 8.3×10^{-4} 1.30×10^{-4}	
Hardness, Mohs' Scale:			
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc		(b) 11.5×10^9 1.67×10^5 1.81	
Compressive Strength: lb/inch²		See below	
Vapor Pressure: °C mm Mercury			
Compressive Strength: lb/inch² Density, gm/cc Ultimate deformation, %		1610 1.81 1.37	

HBX-3

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

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HBX-1; HBX-3

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

<u>Explosive Composition</u>	<u>Moisture, %</u>	<u>Acidity, %</u>	<u>100°C Vac Stab Test</u>		<u>Hygroscopicity, %</u>	
			<u>cc gas</u>	<u>Hours</u>	<u>95% RH</u>	
					<u>30°C</u>	<u>71°C</u>
<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 CaCl₂</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 CaCl₂</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 CaCl₂</u>	0.03	0.082	0.40	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.

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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 Torpex II, for high blast explosive applications.

References:³⁴

(a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PATR No. 2353, November 1950.

(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 Teteryl 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 DAI-19-020-501-ORD-(P)-58).

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

³⁴See footnote 1, page 10.

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HEX-24

Composition:		Molecular Weight:	
%		47.6	
Potassium Perchlorate	32	Oxygen Balance:	
(17 microns)		CO ₂ %	
Aluminum, atomized	48	CO %	
(20 microns)		-42	
RDX (through 325 mesh)	16	Density, gm/cc, Apparent	
Asphaltum (through 100 mesh)	4	Pressed at 20,000 psi	
C/H Ratio		1.39	
Impact Sensitivity, 3 Kg Wt:		2.1	
Bureau of Mines Apparatus, cm	--	Melting Point: °C	
Sample Wt 20 mg		Freezing Point: °C	
Picatinny Arsenal Apparatus, in.	16	Boiling Point: °C	
Sample Wt, mg	24	Refractive Index, n_D²⁰	
Friction Pendulum Test:		n _D ²⁵	
Steel Shoe	Detonates	n _D ³⁰	
Fiber Shoe	Unaffected	Vacuum Stability Test:	
Rifle Bullet Impact Test: Trials		cc/40 Hrs, at	
%		90°C	
Explosions		100°C	
Partials		120°C	
Burned		135°C	
Unaffected		150°C	
Explosion Temperature: °C		270 Gram Bomb Sand Test:	
Seconds, 0.1 (no cap used)	---	Sand, gm	
1	---	12.5	
5	520	Sensitivity to Initiation:	
10		Minimum Detonating Charge, gm	
15		Mercury Fulminate	
20		Lead Azide	
75°C International Heat Test:		Tetryl	
% Loss in 48 Hrs		Ballistic Mortar, % TNT:	
100°C Heat Test:		Trawl Test, % TNT:	
% Loss, 1st 48 Hrs		Plate Dent Test:	
% Loss, 2nd 48 Hrs		Method	
Explosion in 100 Hrs		Condition	
None		Confined	
Flammability Index:		Density, gm/cc	
Hygroscopicity: %		Brisance, % TNT	
None		Detonation Rate:	
Volatility:		Confinement	
None		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	

HEX-24

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<div>Fragmentation Test:</div> <div>90 mm HE, M71 Projectile, Lot WC-91:<div>Density, gm/cc</div><div>Charge Wt, lb</div></div> <div>Total No. of Fragments:<div>For TNT</div><div>For Subject HE</div></div> <div>3 inch HE, M42A1 Projectile, Lot KC-3:<div>Density, gm/cc</div><div>Charge Wt, lb</div></div> <div>Total No. of Fragments:<div>For TNT</div><div>For Subject HE</div></div>	<div>Shaped Charge Effectiveness, TNT = 100:</div> <div><div>Glass Cones</div><div>Steel Cones</div></div> <div>Hole Volume</div> <div>Hole Depth</div>
	<div>Color:Gray</div>
	<div>Principal Uses:HE filler for small caliber projectiles</div>
	<div>Method of Loading:Pressed</div>
	<div>Loading Density: gm/cc</div> <div>Pressed at 20,000 psi2.1</div>
<div>Fragment Velocity: ft/sec</div> <div>At 9 ft</div> <div>At 25½ ft</div> <div>Density, gm/cc</div>	<div>Storage:</div> <div>MethodDry</div> <div>Hazard Class (Quantity-Distance)</div> <div>Compatibility Group</div> <div>ExudationNone</div>
<div>Blast (Relative to TNT):</div> <div>Air:<div>Peak Pressure</div><div>Impulse</div><div>Energy</div></div> <div>Air, Confined:<div>Impulse</div></div> <div>Under Water:<div>Peak Pressure</div><div>Impulse</div><div>Energy</div></div> <div>Underground:<div>Peak Pressure</div><div>Impulse</div><div>Energy</div></div>	<div>Static Tests:</div> <div>20 mm T215E1 Projectile:<div>PA Peak Pressure, psi55</div><div>MFOC 20" Blast Cube44</div><div>APG 24" Blast Cube44</div></div> <div>Static Tests:</div> <div>20 mm M77 Projectile:<div><div>HEX-24</div><div>Tritonal</div><div>Torpex</div></div><div>Foxboro psi1912.413.0</div><div>Catenary psi46----</div><div>Duration, microsec533----</div><div>APG 24" I 1st Cube362432</div></div> <div>Heat of:<div>Combustion, cal/gm4197</div><div>Explosion, cal/gm1858</div><div>Gas volume, cc/gm159</div></div>
<div>Flame Temperature, °K2552</div> <div>Activation Energy, kcal20.4</div> <div>Temp, °C450 to 570</div> <div>Specific reaction rate, k1.64 x 10⁻⁵</div>	

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HEX-48

Composition: % Potassium Perchlorate 32 (17 microns) Aluminum, flaked (1 micron) 48 RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4 C/H Ratio	Molecular Weight: 47.6	
	Oxygen Balance:	
	CO ₂ %	-42
	CO %	-34
	Density: gm/cc Apparent Pressed at 20,000 psi	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	0.69	
	1.62	
	Melting Point: °C	
	Freezing Point: °C	
	Boiling Point: °C	
Friction Pendulum Test: Steel Shoe Partially detonates Fiber Shoe Unaffected	Refractive Index, n_D²⁰	
	n _D ²⁵	
	n _D ³⁰	
	Vacuum Stability Test:	
	cc/40 Hrs, at	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	90°C	----
	100°C	1.52
	120°C	
	135°C	
	150°C	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 545 10 15 20	200 Gram Bomb Sand Test:	
	Sand, gm	23.7
	Sensitivity to Initiation:	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	----
75°C International Heat Test: % Loss in 48 Hrs	Lead Azide	0.20
	Isotryl	0.25
	Ballistic Mortar, % TNT:	
	Trawl Test, % TNT:	
	Plate Dent Test:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
Flammability Index:	Detonation Rate:	
	Confinement	
	Condition	
	Charge Diameter, in.	
	Density, gm/cc	
Hygroscopicity: %	Rate, meters/second	
Volatility:		

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HEX-48Cook-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	HEX-48	Ground	352	264	282
		60,000	676	432	388
T282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EXB 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 EXB Mod 0 projectiles.

HEX-24; HEX-48

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Preparation:

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 20-mm 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:³⁵

(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.

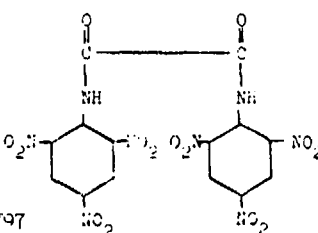
(b) O. E. Sheffield, Properties of MOX-Type Explosive Mixtures, PATR No. 2205, October 1955.

(c) National Northern Corporation, Letter from Dr. C. M. Seffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 1957.

³⁵See footnote 1, page 10.

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

Composition: % C 33.0 H 1.2 N 21.9 O 43.9 C/H Ratio 0.797				Molecular Weight: (C ₁₄ H ₆ N ₆ O ₁₄)	
		Oxygen Balance: CO ₂ % -53.4 CO % -9.4			
		Density: gm/cc		Melting Point: °C Decomposes 302	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 12		Boiling Point: °C		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.40 120°C 135°C 150°C		200 Gram Bomb Sand Test: Sand, gm 52.1	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.30 Tetryl 0.25		Ballistic Mortar, % TNT:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 35L 10 15 20		Treuzl Test, % TNT:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
75°C International Heat Test: % Loss in 48 Hrs		Detonation Rate: Confinement Condition Charge Diameter, in Density, gm/cc Rate, meters/second			
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None					
Flammability Index:					
Hygroscopicity: % 25°C, 90% RH 0.10					
Volatility:					

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

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table> <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>	Glass Cones	Steel Cones	Hole Volume		Hole Depth			
Glass Cones	Steel Cones								
Hole Volume									
Hole Depth									
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Almost white								
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Igniter powder; pyrotechnic compositions Method of Loading: Pressed and extruded Loading Density: gm/cc Storage: <table> <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></td></tr> <tr> <td>Exudation</td><td>None</td></tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None
Method	Dry								
Hazard Class (Quantity-Distance)	Class 9								
Compatibility Group									
Exudation	None								

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2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)Solubility in the following substances:

<u>Solvent</u>	
Nitrobenzene	43 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 80-100°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 Buchner 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 51, 462 (1892)).

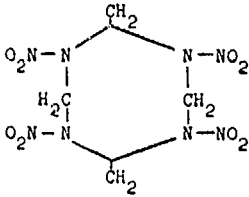
References: 36

- (a) L. Cowen and R. Diggins, 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-TF1-88, 20 December 1954.
- (c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 130,330, 11 April 1951.
- (d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

³⁶See footnote 1, page 10.

beta-HMX (a)

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Composition: % C 16.2 H 2.7 N 37.9 O 43.2 C/H Ratio 0.095				Molecular Weight: (C ₄ H ₈ N ₈ O ₈) 296	
				Oxygen Balance: CO ₂ % -21.6 CO % 0.0	
				Density: gm/cc Crystal 1.90	
				Melting Point: °C Capillary method 273 Koffler Micro Hot Stage 280	
				Freezing Point: °C	
				Boiling Point: °C	
				Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 23				Vacuum Stability Test: cc/40 Hrs. at 90°C 100°C 0.37 120°C 0.45 135°C -- 150°C 0.62	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Unaffected				200 Gram Bomb Sand Test: Sand, gm 60.4	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.30 Tetryl	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 380 1 -- 5 327 10 306 15 -- 20 --				Ballistic Mortar, % TNT: 150	
75°C International Heat Test: % Loss in 48 Hrs				Trauzl Test, % TNT: 145	
100°C Heat Test: % Loss, 1st 48 Hrs 0.05 % Loss, 2nd 48 Hrs 0.03 Explosion in 100 Hrs None				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:				Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.84 Rate, meters/second 9124	
Hygroscopicity: % 30°C, 95% RH (c) 0.00					
Volatility:					

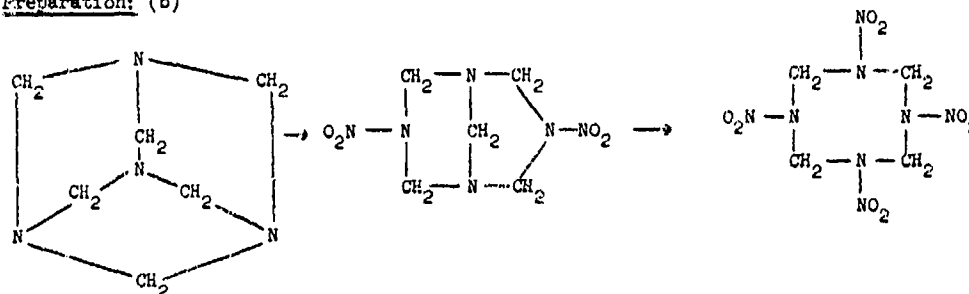
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beta-HMX

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc		Decomposition Equation: (e) Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase		10 ^{19.7} 52.7 271-314 Liquid
Heat of: Combustion, cal/gm Explosion, cal/gm (e) Gas Volume, cc/gm Formation, cal/gm (e) Fusion, cal/gm		Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4		2362 1356 -60.5
Specific Heat: cal/gm/°C °C -75 0.153 0 0.228 25 0.248 50 0.266 75 0.282		Recrystallized (g) °C 85 0.288 90 0.290 100 0.295 125 0.307 150 0.315		
Burning Rate: cm/sec		Bomb Drop Test: 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		
Thermal Conductivity: cal/sec/cm/°C				
Coefficient of Expansion: Linear, %/°C Volume, %/°C				
Hardness, Mohs' Scale: (e) 2.3				
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc				
Compressive Strength: lb/inch²				
Vapor Pressure: °C mm Mercury				

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 $45 \pm 1^\circ\text{C}$, 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 $279.5^\circ\text{--}280.5^\circ\text{C}$. Recrystallization from nitromethane yields material melting at $281^\circ\text{--}282^\circ\text{C}$.

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):

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beta-HMXProcedure:

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 steambath 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	26.50%
Samples taken during process -	2.4 gm	0.48%
Loss during process		2.24%
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 L (dry) Group M (wet)
Exudation	None

References:³⁷

- (a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-TML-23, 7 April 1952.
- (b) W. E. Bachmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.
- (c) S. Livingston, Characteristics of Explosives HMX and DPEHN, PATR No. 1561, 6 September 1945.
- (d) R. J. Finkelstein and G. Gamov, 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:
- | | | | | |
|----------|----------|----------|----------|--------------|
| <u>1</u> | <u>3</u> | <u>6</u> | <u>7</u> | <u>9</u> |
| 1741 | 2183 | 2016 | 1737 | 1709
2059 |
- (g) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1955.

³⁷See footnote 1, page 10.

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HTA-3

Composition:		Molecular Weight:		91
%		Oxygen Balance:		
HBOX	49	C ₂ %		-51
TNT	29	O %		-27
Aluminum	22	Density: gm/cc		Cast 1.90
C/H Ratio		Melting Point: °C		
Impact Sensitivity, 2 Kg Wt:		Freezing Point: °C		
Bureau of Mines Apparatus, cm		Boiling Point: °C		
Sample Wt 20 mg		Refractive Index, n_D²⁰		
Picatinny Arsenal Apparatus, in.		n _D ²⁵		
Sample Wt, mg		n _D ³⁰		
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe		cc/40 Hrs, at		
Fiber Shoe		90°C		----
Unaffected		100°C		----
Rifle Bullet Impact Test: 10 Trials, %		120°C		0.37
3/16" Steel		135°C		
1/8" Al		150°C		
Explosions		200 Gram Bomb Sand Test:		
Partial		Sand, gm		61.3
Burned		Sensitivity to Initiation:		
Unaffected		Minimum Detonating Charge, gm		
Explosion Temperature: °C		Mercury Fulminate		----
Seconds, 0.1 (no cap used)		Lead Azide		0.30
1		Tetryl		----
5 Flames erratically		Ballistic Mortar, % TNT.		120
10		Treuzl Test, % TNT:		
15		Plate Dent Test:		
20		Method		
75°C International Heat Test:		Condition		
% Loss in 48 Hrs		Confined		
100°C Heat Test:		Density, gm/cc		
% Loss, 1st 48 Hrs		Brisance, % TNT		
% Loss, 2nd 48 Hrs		Detonation Rate:		
Explosion in 100 Hrs		Confinement		None
Flammability Index:		Condition		Cast
Hygroscopicity: %		Charge Diameter, in.		1.0
Volatility:		Density, gm/cc		1.90
		Rate, meters/second		7866

HTA-3

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Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3687 Explosion, cal/gm 1190 Gas Volume, cc/gm 680 Formation, cal/gm ---- Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C 32° to 74°C 0.245	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 2260 See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch ² * Average (10 tests) 2260 High 2530 Low 1910	Ultimate Deformation: 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.

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HTA-3

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: HE projectile and bomb filler Method of Loading: Cast Loading Density: gm/cc 1.90
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Work to Produce Rupture: ft-lb./inch³ * <div style="display: flex; justify-content: space-between;"> Average (10 tests) 2.77 </div> <div style="display: flex; justify-content: space-between;"> High 3.39 </div> <div style="display: flex; justify-content: space-between;"> Low 2.40 </div> Efflux Viscosity, Saybolt Seconds: 24.8 <p>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (5,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</p>

HTA-3

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Modulus of Elasticity: *

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

* Test specimen 1/4" 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:³⁸

(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-HL-509, 5 May 1958.

³⁸See footnote 1, page 10.

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Lead Azide

Composition: %	N 26.8		$N \equiv N - N - Pb - N - N \equiv N$
	Pb 71.2		
	C/H Ratio		
	Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		Pure 10	Dextrinated 17
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.		3	5
Sample Wt, mg		30	28
Friction Pendulum Test:			
Steel Shoe		Explodes	
Fibre Shoe		Explodes	
Rifle Bullet Impact Test: Trials			
Explosions		%	
Partials			
Burned			
Unaffected			
Explosion Temperature: °C			
Seconds, 0.1 (no cap used)		396	
1		356	
5 Explodes		340	
10		335	
15		335	
20		335	
75°C International Heat Test:			
% Loss in 48 Hrs			
100°C Heat Test:			
% Loss, 1st 48 Hrs		0.34	
% Loss, 2nd 48 Hrs		0.05	
Explosion in 100 Hrs		None	
Flammability Index:			
Hygroscopicity: % <u>Dextrinated</u> <u>Not Dextrinated</u>			
30°C, 90% RH		0.0 0.03	
Volatility:			
Molecular Weight: (PbN ₆)		291	
Oxygen Balance:			
CO ₂ %		-5.5	
CO %		-5.5	
Density: gm/cc		Crystal	4.80
		Dextrinated	4.38
Melting Point: °C		Decomposes	
Freezing Point: °C			
Boiling Point: °C			
Refractive Index, n_D²⁰			
n _D ²⁰			
n _D ²⁵			
Vacuum Stability Test:		<u>Dextrinated</u>	
cc/40 Hrs, at			
90°C			
100°C		1.0	
120°C		0.07	
135°C			
150°C			
200 Gram Bomb Sand Test:			
Sand, gm			
Black powder fuse		19.0	
Sensitivity to Initiation:			
Minimum Detonating Charge, gm			
Mercury Fulminate			
Lead Azide			
Tetryl			
Ballistic Mortar, % TNT:			
Treuxl Test, % TNT: (a)		39	
Plate Dent Test:			
Method			
Condition			
Confined			
Density, gm/cc			
Brisance, % TNT			
Detonation Rate:		<u>Pure Lead Azide</u>	
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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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color:
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Lead AzideCompatibility 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 ($\frac{1}{2}\%$ moisture) after 29 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>	<u>Lead Azide</u>	<u>Lead Azide</u>
	<u>Dry</u>	<u>plus</u> <u>25% Water</u>	<u>plus</u> <u>20% Water</u>	<u>plus 20%</u> <u>Ethyl Alcoh-</u> <u>ol (95%)</u>

Friction Pendulum Test:

(All LA dextrinated)

<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
Cracklings		0	2	0	2	0
Unaffected	0	10	10	10	1	0

Impact Sensitivity, 2 Kg Wt:

(All LA dextrinated)

PA Apparatus, inches	4	9	9	4
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Activation Energy: (c)

Kcal/mole	23.74
Induction Period, seconds	0.5-10

Initiating Efficiency, Grams Required to Give Complete Initiations of:

	<u>Dextrinated Azide (gm)</u>
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

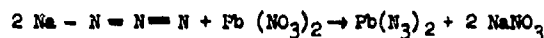
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Compatibility of Dextrinated Lead Azide with Black Powder:
100°C Vacuum Stability Test, cc/40 hr:

<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>%</u>
20	0.05

Preparation of Lead Azide (Dextrinated): (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 384,792) 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 "dextrinated" 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 2% 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.

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Lead Azide

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

References: ³⁹

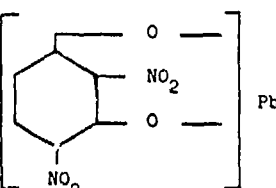
- (a) Ph. Naoum, Z ges Schiess Sprengstoffw, 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR #2224, November 1955.
- (d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

<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>
550	561	832	393	534	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
		1152		2204		1556	2227	1388	999
		1352						1528	2179
		1372						1838	
								2198	

³⁹See footnote 1, page 10.

Lead 2,4-Dinitroresorcinate (LDNR)

AMCP 706-177

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

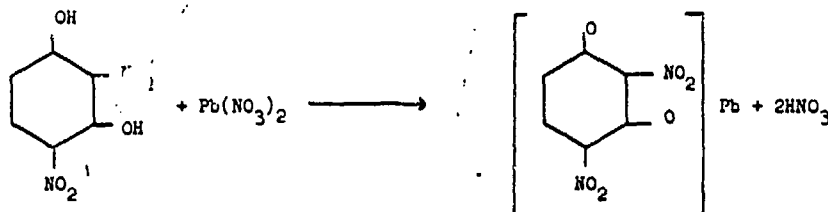
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Lead 2,4-Dinitroresorcinate (LDNR)

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec: At 9 ft At 25¼ ft Density, gm/cc	Color: Red or yellow									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Electric detonators									
	Method of Loading: Pressed									
	Loading Density: gm/cc									
	Storage: <table> <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></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
Method	Wet									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group										
Exudation	None									
	Initiating Efficiency: 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi. Heat of: <table> <tr> <td>Explosion, cal/gm</td> <td>270</td> </tr> </table>	Explosion, cal/gm	270							
Explosion, cal/gm	270									

Lead 2,4-Dinitroresorcinate (LDNR)

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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 Hübl 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 dinitrosoresorcinol 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. Hopper, PATR No. 480, March 1934). The LDNR 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:⁴⁰

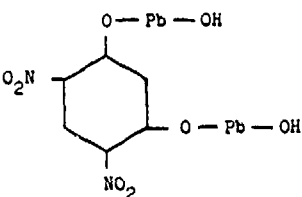
(a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

<u>0</u>	<u>3</u>	<u>4</u>	<u>8</u>	<u>9</u>
480	453	1004	1328	859
580			1448	1079

⁴⁰See footnote 1, page 10.

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Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

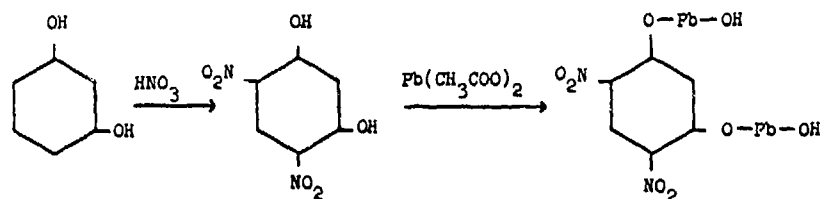
Composition: % C 11.2 H 0.6 N 4.3 O 19.8 Pb 64.1 C/H Ratio 0.177		Molecular Weight: (Pb ₂ C ₆ H ₄ N ₂ O ₈) 646	
		Oxygen Balance: CO ₂ % -20 CO % -5	
		Density: gm/cc	
		Melting Point: °C 213	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20		Boiling Point: °C	
		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Fibre Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm Black Powder fuse 15	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 295 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 43 Hrs		Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: %			
Volatility:			

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Red or yellow Principal Uses: Electric detonators									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Pressed Loading Density: gm/cc Storage: <table border="0"> <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></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
Method	Wet									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group										
Exudation	None									
	Initiating Efficiency: 0.4 gm LDNR Basic does not initiate teteryl pressed at 3000 psi.									

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Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)Preparation:

(a) One hundred grams of pure resorcin 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 resorcin 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 resorcin 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.

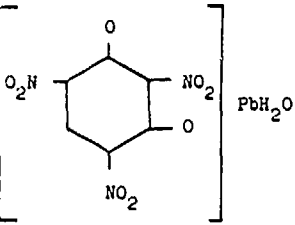
(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C , the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation 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-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Tytke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin 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-Dinitroresorcin and Lead 4,6-Dinitroresorcinates"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcin 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).

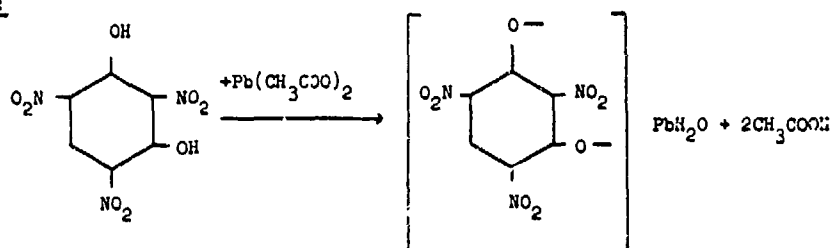
Lead Styphnate

AMCP 706-177

Composition: % C 15.4 H 0.6 N 9.0 O 30.8 Pb 44.2 C/H Ratio 0.320				Molecular Weight: (PbC ₆ H ₃ N ₃ O ₉) 468	
				Oxygen Balance: CO ₂ % -19 CO % 2	
				Density: gm/cc Crystal 3.02	
				Melting Point: °C Explodes 260-310	
				Freezing Point: °C	
				Boiling Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 17 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) 8 Sample Wt, mg 22				Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Detonates				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.4 120°C 0.3 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected				200 Gram Bomb Sand Test: Sand, gm 24 Black powder fuse 11.1	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 Explodes 282 10 276 15 272 20 267				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Trace* Lead Azide Trace* Tetryl * <.001 gm, alternative	
				Ballistic Mortar, % TNT:	
73°C International Heat Test: % Loss in 48 Hrs				Treuzl Test, % TNT: (a) 40	
100°C Heat Test: % Loss, 1st 48 Hrs 0.38 % Loss, 2nd 48 Hrs 0.73 Explosion in 100 Hrs None				Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:				Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 2.9 Rate, meters/second 5200	
Hygroscopicity: % 25°C, 100% RH 0.05 30°C, 90% RH 0.02					
Volatility:					

Lead Styphnate

AMCP 706-177

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 80°C, on:

Explosion Temperature Test Value	N11
Sand Test Value	N11
Sensitivity to Initiation	N11

Solubility, gm/100 gm (%) in:Glycol Diacetate

°C	%
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)). Moisek 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 Kasan (Russia) 2, 81-5 (1935)).

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Lead StyphnateDestruction 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:⁴¹

- (a) Report AC-956/Org Ex 74.
- (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, PATR No. 2224, November 1955.
- (d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

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

⁴¹See footnote 1, page 10.

Mannitol Hexanitrate (Nitromannite)

AMCP 706-177

Composition: % C 15.9 H 1.8 N 18.6 O 63.8 C/H Ratio 0.133		$ \begin{array}{c} \text{CH}_2\text{ONO}_2 \\ \\ \text{O}_2\text{NOCH} \\ \\ \text{O}_2\text{NOCH} \\ \\ \text{HCONO}_2 \\ \\ \text{HCONO}_2 \\ \\ \text{CH}_2\text{ONO}_2 \end{array} $		Molecular Weight: ($\text{C}_6\text{H}_8\text{N}_6\text{O}_{18}$) 452
		Oxygen Balance: CO ₂ % 7.1 CO % 28.3		
		Density: gm/cc 1.73		
		Melting Point: °C 112-113		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 11 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg 11		Boiling Point: °C Decomposes 150		
		Refractive Index, n_D^{20} n_D^{25} n_D^{30}		
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 68.5		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 160-170 (a) 1 232 (b) 5 175 (c) 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.06 Tetryl --		
		Ballistic Mortar, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs 0.4		Treuzl Test, % TNT: (c) 172		
100°C Heat Test: % Loss, 1st 48 Hrs -- % Loss, 2nd 48 Hrs -- Explosion in 100 Hrs (Frothed) 48 hours		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:		Detonation Rate: (d) Confinement Yes Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.73 Rate, meters/second 8260		
Hygroscopicity: % 30°C, 90% RH 0.17				
Volatility:				

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Mannitol Hexanitrate (Nitromannite)

Fragmentation Test: 90 mm HE, 1171 Projectile, Lot VC-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	Shaped Charge Effectiveness, TNT = 100: <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>	Glass Cones	Steel Cones	Hole Volume		Hole Depth						
Glass Cones	Steel Cones											
Hole Volume												
Hole Depth												
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Principal Uses: Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j) Method of Loading: PRESSED Loading Density: gm/cc Storage: <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></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None			
Method	Dry											
Hazard Class (Quantity-Distance)	Class 9											
Compatibility Group												
Exudation	None											
Blot (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	65.5°C KI Test: <table border="0"> <tr> <td>Minutes</td> <td>6</td> </tr> </table> Heat of: (e, i, g) <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>1515</td> <td>1525</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1390</td> <td>1454 1468 1520</td> </tr> <tr> <td>Formation, cal/gm</td> <td>337</td> <td>345 366</td> </tr> </table>	Minutes	6	Combustion, cal/gm	1515	1525	Explosion, cal/gm	1390	1454 1468 1520	Formation, cal/gm	337	345 366
Minutes	6											
Combustion, cal/gm	1515	1525										
Explosion, cal/gm	1390	1454 1468 1520										
Formation, cal/gm	337	345 366										

Mannitol Hexanitrate (Nitromannite)

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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 18.2% 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 (Comp 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 HM and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Berthelot, Sarran and Vieille, Domonte, 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:⁴²

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

⁴²See footnote 1, page 10.

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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. Naoum, Z ges Schiess - Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).

(d) H. Kast, Z angew Chem, 36, 74 (1923).

(e) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262, (1934).

Landolt and Börnstein, E III, p. 2914.

(f) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, (1928), pp. 156, 247-250.

(g) A. Schmidt, Z ges Schiess - Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissand and P. Lhoste, "Structure and Stability of Nitric Esters," Comp rend 224, 1016-18 (1947). 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.

(h) Sarrau and Vielle, Mém poudr 2, 161 (1884-1889).

(i) E. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).

(j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).

(k) B. T. Fedoroff, Handbook of Explosives and Related Items, Picatinny Arsenal (unpublished).

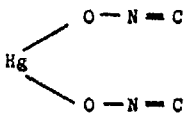
(l) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TM-16, 23 January 1952.

(m) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:

<u>2</u>	<u>4</u>	<u>5</u>	<u>6</u>
1352	24 64	85	6

Mercury Fulminate

AMCP 706-177

Composition: % C 8.4 N 9.8 O 11.2 Hg 70.6 C/H Ratio		Molecular Weight: (HgC ₂ N ₂ O ₂) 285
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 5; (1 kg wt) 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 2; (1 lb wt) 4 Sample Wt, mg 30	Oxygen Balance: CO ₂ % -17 CO % -5.5	Density: gm/cc Crystal 4.43
		Making Point: °C Decomposes
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Explodes	Freezing Point: °C	Boiling Point: °C
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	Vacuum Stability Test: cc/40 Hrs, at °C 100°C Explodes 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm Black powder fuse 23.4
Explosion Temperature: °C Seconds, 0.1 (no cap used) 263 1 239 5 Explodes 210 10 199 15 194 20 190		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
75°C International Heat Test: % Loss in 48 Hrs 0.18	Ballistic Mortar, % TNT:	Trauzl Test, % TNT: (a) 51
100°C Heat Test: Exploded in 16 hours % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	Detonation Rate: Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 3500 4250 5000
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.02	Volatility:	

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Mercury Fulminate

Fragmentation Test: 90 mm HE, A171 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	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: White to gray Principal Uses: Detonators and ingredient of priming compositions Method of Loading: psi x 10 ³ 3 5 10 12 15 20 3.00 3.20 3.60 3.70 3.82 4.00 Loading Density: gm/cc: Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (ww.) Exudation None																								
Fragment Velocity: ft/sec At 9 ft At 25 1/2 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	Sstab Sensitivity: <table><tr><th>Density</th><th colspan="3">Firing Point (inch-ounces)</th></tr><tr><th>gm/cc</th><th>0%</th><th>50%</th><th>100%</th></tr><tr><td>3.91</td><td>3.2</td><td>4.3</td><td>5.5</td></tr><tr><td>4.26</td><td>1.6</td><td>2.6</td><td>5.5</td></tr><tr><td>4.32</td><td>1.6</td><td>2.6</td><td>4.0</td></tr><tr><td>4.50</td><td>1.6</td><td>2.5</td><td>4.0</td></tr></table> Activation Energy: kcal/mol 29.81 Induction Period, sec 0.5-10 Heat of: Combustion, cal/gm 938 Explosion, cal/gm 427 Gas Volume, cc/gm 243 Formation, cal/gm -226 Specific Heat: cal/gm/°C 1.1 Thermal Conductivity: cal/sec/cm/°C 1 x 10 ⁻⁴	Density	Firing Point (inch-ounces)			gm/cc	0%	50%	100%	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
Density	Firing Point (inch-ounces)																								
gm/cc	0%	50%	100%																						
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																						

Mercury Fulminate

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Initiating Efficiency; Grams Required to Give Complete Initiation of:

	<u>Fulminate, gm</u>
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) 0.025

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

<u>Months Storage</u>	<u>Recrystallized Lots</u>				<u>Uncrystallized Lots</u>	
	<u>979</u>	<u>980</u>	<u>981</u>	<u>982</u>	<u>505.6-7/31</u>	<u>505.3-5/11</u>
0	99.75	99.77	99.79	99.79	98.86	
4						98.7
6	99.38	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	98.46	95.90	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 protectively coated if used with fulminate.

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

<u>°C</u>	<u>%</u>
12	0.07
49	0.18

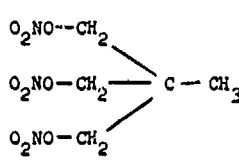
Mercury Fulminate

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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	866	567	788	999
680		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 Trimethylolethane Trinitrate)

Composition: %			Molecular Weight: (C ₅ H ₉ N ₃ O ₉) 255	
C	23.5		Oxygen Balance:	
H	3.5		CO ₂ % -35	
N	16.6		CO % -3	
O	56.4			
C/H Ratio 0.150			Density: gm/cc Liquid 1.47	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 47; (1 lb wt) 4 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20			Melting Point: °C -3	
			Freezing Point: °C	
			Boiling Point: °C	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe			Refractive Index, n_D²⁰	
			n _D ²⁰ 1.4752	
			n _D ²⁰	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected			Vacuum Stability Test:	
			cc/40 Hrs, at 90°C	
			100°C	cc/gm 1.9
			120°C	
			135°C	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 235 10 15 20			150°C	
			200 Gram Bomb Sand Test:	
			Sand, gm 43.7	
			Sensitivity to Initiation:	
			Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs			Ballistic Mortar, % TNT: (a) 136	
			Trauzl Test, % TNT: (b) 140	
100°C Heat Test: % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None			Plate Dent Test:	
			Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:			Detonation Rate:	
Hygroscopicity: % 30°C, 90% RH 0.07			Confinement Condition	
			Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility: 60°C, mg/cm ² /hr 24				

Metriol Trinitrate (MTN) Liquid

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth											
	Glass Cones	Steel Cones																	
Hole Volume																			
Hole Depth																			
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Color: Oily, slightly turbid Principal Uses: Ingredient of rocket and double base propellants																		
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Method of Loading: Loading Density: gm/cc Storage: <table border="0"> <tr> <td>Method</td> <td>Liquid</td> </tr> <tr> <td colspan="2">Hazard Class (Quantity-Distance)</td> </tr> <tr> <td colspan="2">Compatibility Group</td> </tr> <tr> <td colspan="2">Exudation</td> </tr> </table> Solubility in Water, gm/100 gm, at: <table border="0"> <tr> <td>25°C</td> <td>< 0.015</td> </tr> <tr> <td>60°C</td> <td>< 0.015</td> </tr> </table> Heat of: <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2642</td> </tr> </table> Hydrolysis, % Acid: <table border="0"> <tr> <td>10 days at 22°C</td> <td>0.018</td> </tr> <tr> <td>5 days at 60°C</td> <td>0.115</td> </tr> </table>	Method	Liquid	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation		25°C	< 0.015	60°C	< 0.015	Combustion, cal/gm	2642	10 days at 22°C	0.018	5 days at 60°C	0.115
Method	Liquid																		
Hazard Class (Quantity-Distance)																			
Compatibility Group																			
Exudation																			
25°C	< 0.015																		
60°C	< 0.015																		
Combustion, cal/gm	2642																		
10 days at 22°C	0.018																		
5 days at 60°C	0.115																		

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Metriol Trinitrate (MTN) LiquidPreparation:

Metriol (trimethylolmethylethane) 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 (40.7 gm) is then about 196°C (Hosaeus gives 199°C).

Metriol is nitrated by carefully mixing it with 3.5 parts of 65/35 HNO₃/H₂SO₄ 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: ⁴⁴

- (a) A. E. Blatt, 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 Metriol Trinitrate: 1616 and 1817.

⁴⁴See footnote 1, page 10.

Minol-2

AMCP 706-177

Composition: % Ammonium Nitrate 40 TNT 40 Aluminum 20 C/H Ratio	Molecular Weight: 71	
	Oxygen Balance: CO ₂ % -38 CO % -20	
	Density: gm/cc 1.62-1.68	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 2.1 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 435 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
	Ballistic Mortar, % TNT: (a)	143
	Trauzl Test, % TNT: (b)	165
	Plate Dant Test: (c)	
	Method	B
75°C International Heat Test: % Loss in 48 Hrs	Condition	Pressed
	Confined	No
	Density, gm/cc	1.73
	Brisance, % TNT	66
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: (d)	
	Confinement	None
	Condition	Cast
Flammability Index: 100	Charge Diameter, in.	1.6
	Density, gm/cc	1.68
Hygroscopicity: %	Rate, meters/second	5820
Volatility:		

AMCP 706-177

Minol-2

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc		Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase	
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm		Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1½ 1½ 1½	
Specific Heat: cal/gm/°C At -5°C Density, gm/cc			
Burning Rate: cm/sec			
Thermal Conductivity: cal/sec/cm/°C Density, gm/cc		Bomb Drop Test: 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	
Coefficient of Expansion: Linear, %/°C Volume, %/°C			
Hardness, Mohs' Scale:			
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc			
Compressive Strength: lb/inch² (b) Density, gm/cc			
Vapor Pressure: °C mm Mercury			

Minol-2

AMCP 706-177

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
	Color: Gray
	Principal Uses: Bombs and depth charges
	Method of Loading: Cast
	Loading Density: gm/cc 1.62-1.68
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): 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	Preparation: 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.

AMCP 706-177

Minol-2Origin:

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:⁴⁵

- (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. 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) 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.

⁴⁵See footnote 1, page 10.

MOX-1

AMCP 706-177

Composition:		Molecular Weight: 40.6	
% Oxidizing agent (Ammonium Perchlorate) 35.0 Aluminum, atomized 26.2 Cupric Oxide ---- Magnesium, atomized 26.2 Other ingredient (Tetryl) 9.7 Calcium Stearate 1.9 Graphite, artificial 1.0 C/H Ratio		Oxygen Balance: CO ₂ % -44 CO % -37	
		Density: gm/cc Pressed 2.0	
		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 22		Boiling Point: °C	
		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Detonates Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.47 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 10.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 285 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.25	
		Ballistic Mortar, % TNT:	
		Trouzi Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None		Plate Dent Test: Method Condition Confined Density, gm/cc Risance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.10 % Loss, 2nd 48 Hrs 0.01 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:			
Hygroscopicity: %			
Volatility:			

AMCP 706-177

MOX-1

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Color: Gray powder mixture
Blunt (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Small caliber antiaircraft projectiles
	Method of Loading: Pressed
	Loading Density: gm/cc At 30,000 psi ~ 2.0
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Bureau of Explosives Classification Class A Exudation
	Heat of: <div> Combustion, cal/gm 4087 Explosion, cal/gm 2087 Gas volume, cc/gm 212 </div> Performance Tests: 20 mm T215E1 Projectile: <div> MFOC Pressure Cube 35 APC Blast Cube 40 </div> Activation Energy: <div> kcal/mol 12.5 Temp, °C 300 to 380 Time to ignition, seconds 1.78×10^{-4} </div>

MOX-2B

AMCP 706-177

Composition:		Molecular Weight:		42
%		Oxygen Balance:		
Oxidizing agent (Ammonium Perchlorate)	35.0	CO ₂ %	-49	
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_D²⁰		
*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.		n _D ²⁰		
Impact Sensitivity, 2 Kg Wt:		n _D ²⁰		
Bureau of Mines Apparatus, cm	--	Vacuum Stability Test:		
Sample Wt 20 mg		cc/40 Hrs, at		
Picatinny Arsenal Apparatus, in.	12	90°C	----	
Sample Wt, mg	24	100°C	0.21	
Friction Pendulum Test:		120°C		
Steel Shoe	Unaffected	135°C		
Fiber Shoe	Unaffected	150°C		
Rifle Bullet Impact Test:		200 Gram Bomb Sand Test:		
	Trial	Sand, gm	11.5	
	%	Sensitivity to Initiation:		
Explosions		Minimum Detonating Charge, gm		
Partials		Mercury Fulminate	----	
Burned		Lead Azide	0.20	
Unaffected		Tetryl	0.20	
Explosion Temperature: °C		Ballistic Matter, % TNT:		
Seconds, 0.1 (no cap used)	---	Treuzl Test, % TNT:		
1	---	Plate Dent Test:		
5	375	Method		
10		Condition		
15		Confined		
20		Density, gm/cc		
75°C International Heat Test:		Brisance, % TNT		
% Loss in 48 Hrs		Detonation Rate:		
Discoloration, fumes, odor	None	Confinement		
100°C Heat Test:		Condition		
% Loss, 1st 48 Hrs	0.27	Charge Diameter, in.		
% Loss, 2nd 48 Hrs	0.12	Density, gm/cc		
Explosion in 100 Hrs	None	Rate, meters/second		
Flammability Index:				
Hygroscopicity: %				
Volatility:				

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MOX-23

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: HE filler for small caliber projectiles Method of Loading: Pressed Loading Density: gm/cc 2.0																											
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Bureau of Explosives Class A Exudation None																											
Blast (Relative to TNT): <table border="0"> <tr> <td>Air, Bare Charge:</td> <td><u>EW*</u></td> <td><u>EV*</u></td> </tr> <tr> <td>Peak Pressure</td> <td>1.02</td> <td>1.34</td> </tr> <tr> <td>Impulse</td> <td>1.08</td> <td>1.41</td> </tr> <tr> <td>Energy</td> <td></td> <td></td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td>1.96</td> </tr> </table> Air, Confined: Impulse Cased Charge in Air:** <table border="0"> <tr> <td>Peak Pressure</td> <td>1.09</td> <td>1.44</td> </tr> <tr> <td>Impulse</td> <td>1.16</td> <td>1.53</td> </tr> <tr> <td>Energy</td> <td>----</td> <td>----</td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td>1.98</td> </tr> </table> Underground: Peak Pressure Impulse Energy *EW, equivalent weight as compared to TNT; EV, equivalent volume as compared to TNT. **Strong paper-base phenolic case.	Air, Bare Charge:	<u>EW*</u>	<u>EV*</u>	Peak Pressure	1.02	1.34	Impulse	1.08	1.41	Energy			Density, gm/cc		1.96	Peak Pressure	1.09	1.44	Impulse	1.16	1.53	Energy	----	----	Density, gm/cc		1.98	Heat of: Combustion, cal/gm 4484 Explosion, cal/gm 1472 Gas volume, cc/gm 221 Performance Tests: <u>20 mm T215E1 Projectile:</u> NFOC Pressure Cube 29 APG Blast Cube 30 Aviation Energy: kcal/mol 7.6 Temp, °C 340 to 470 Time to ignition, seconds 1.39×10^{-2}
Air, Bare Charge:	<u>EW*</u>	<u>EV*</u>																										
Peak Pressure	1.02	1.34																										
Impulse	1.08	1.41																										
Energy																												
Density, gm/cc		1.96																										
Peak Pressure	1.09	1.44																										
Impulse	1.16	1.53																										
Energy	----	----																										
Density, gm/cc		1.98																										

MOX-2B

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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>Unconfined</u>	<u>Confined</u>	<u>Unconfined</u>
	m/s	m/s	m/s	m/s
Ground			4730	
30,000	Charge would not propagate detonation.		4530(3)	Charge would not propa- gate detona- tion.
60,000			4430	
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>30,000</u>	<u>60,000</u>	<u>90,000</u>
		m/s	m/s	m/s	m/s
MOX-2B, density, gm/cc 207	1	2012	**	**	**
	2	3314	3351	3247	**

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

**Charge would not propagate detonation.

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MOX-3B

Composition:		Molecular Weight: 45.6	
Oxidizing agent (Potassium Nitrate)	18	Oxygen Balance:	
Aluminum, atomized	50	CO ₂ %	-52
Cupric Oxide	--	CO %	-43
Magnesium, atomized	--	Density: gm/cc Pressed 2.0	
Other ingredients*	32	Melting Point: °C	
Calcium Stearate**	2.0	Freezing Point: °C	
Graphite, artificial**	1.0	Boiling Point: °C	
*29.1% RDX, 0.9% wax, and 2.0% TNT.		Refractive Index, n_D²⁰	
**Per cent added.		n_D²⁵	
Impact Sensitivity, 2 Kg Wt:		n_D³⁰	
Bureau of Mines Apparatus, cm	--	Vacuum Stability Test:	
Sample Wt 20 mg		cc/40 Hrs, at	
Picatinny Arsenal Apparatus, in.	17	90°C	----
Sample Wt, mg	24	100°C	0.57
Friction Pendulum Test:		120°C	
Steel Shoe	Unaffected	135°C	
Fiber Shoe	Unaffected	150°C	
Rifle Bullet Impact Test: Trials		200 Gram Bomb Sand Test:	
	%	Sand, gm	33.2
Explosions		Sensitivity to Initiation:	
Partials		Minimum Detonating Charge, gm	
Burned		Mercury Fulminate	----
Unaffected		Lead Azide	0.20
Explosion Temperature: °C		Tetryl	0.15
Seconds, 0.1 (no cap used)	---	Ballistic Mortar, % TNT:	
1	---	Trauzl Test, % TNT:	
5	540	Plate Dent Test:	
10		Method	
15		Condition	
20		Confined	
75°C International Heat Test:		Density, gm/cc	
% Loss in 48 Hrs		Brisance, % TNT	
Discoloration, fumes, odor	None	Detonation Rate:	
100°C Heat Test:		Confinement	
% Loss, 1st 48 Hrs	0.35	Condition	
% Loss, 2nd 48 Hrs	0.13	Charge Diameter, in.	
Explosion in 100 Hrs	None	Density, gm/cc	
Flammability Index:		Rate, meters/second	
Hygroscopicity: %			
Volatility:			

MOX-3B

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones of Cones Hole Volume Hole Depth Color: Gray powder mixture Principal Uses: Small caliber antiaircraft projectiles
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Method of Loading: Pressed Loading Density: gm/cc At 30,000 psi ~ 2.0 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Bureau of Explosives Class A
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Heat of: Combustion, cal/gm 4331 Explosion, cal/gm 980 Gas volume, cc/gm 232 Performance Tests: 20 mm T215E1 Projectile: NFOC Pressure Cube 37 APG Blast Cube 52 Activation Energy: kcal/mol Values not included Temp, °C due to erratic ig- Time to ignition, nition under condi- seconds tions of test.

AMCP 706-177

MOX-4B

Composition:		Molecular Weight: 48	
% 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.		Oxygen Balance: CO ₂ % -53 CO % -43	
		Density: gm/cc Pressed 2.0	
		Melting Point: °C	
		Freezing Point: °C	
		Boiling Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Sparks Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.67 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 33.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 610 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15	
		Ballistic Mortar, % TNT:	
		Trawl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.22 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:			
Hygroscopicity: %			
Volatility:			

MOX-4B

AMCP 706-177

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-9V: 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	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																									
	Glass Cones	Steel Cones																															
Hole Volume																																	
Hole Depth																																	
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	<table border="0"> <tr> <td>Color:</td> <td>Gray powder mixture</td> </tr> <tr> <td>Principal Uses:</td> <td>Small caliber antiaircraft projectiles</td> </tr> <tr> <td>Method of Loading:</td> <td>Pressed</td> </tr> <tr> <td>Loading Density: gm/cc At 30,000 psi</td> <td>~2.0</td> </tr> </table>	Color:	Gray powder mixture	Principal Uses:	Small caliber antiaircraft projectiles	Method of Loading:	Pressed	Loading Density: gm/cc At 30,000 psi	~2.0																								
Color:	Gray powder mixture																																
Principal Uses:	Small caliber antiaircraft projectiles																																
Method of Loading:	Pressed																																
Loading Density: gm/cc At 30,000 psi	~2.0																																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	<table border="0"> <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 I Bureau of Explosives Class A</td> </tr> <tr> <td>Heat of:</td> <td></td> </tr> <tr> <td>Combustion, cal/gm</td> <td>4392</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>709</td> </tr> <tr> <td>Gas volume, cc/gm</td> <td>208</td> </tr> <tr> <td>Performance Tests:</td> <td></td> </tr> <tr> <td>20 mm T215EL Projectile:</td> <td></td> </tr> <tr> <td>NFOC Pressure Cube</td> <td>43</td> </tr> <tr> <td>APG Blast Cube</td> <td>53</td> </tr> <tr> <td>Aviation Energy:</td> <td></td> </tr> <tr> <td>kcal/mol</td> <td>Values not included</td> </tr> <tr> <td>Temp, °C</td> <td>due to erratic igni-</td> </tr> <tr> <td>Time to ignition, seconds</td> <td>tion under conditions of test.</td> </tr> </table>	Storage:		Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I Bureau of Explosives Class A	Heat of:		Combustion, cal/gm	4392	Explosion, cal/gm	709	Gas volume, cc/gm	208	Performance Tests:		20 mm T215EL Projectile:		NFOC Pressure Cube	43	APG Blast Cube	53	Aviation Energy:		kcal/mol	Values not included	Temp, °C	due to erratic igni-	Time to ignition, seconds	tion under conditions of test.
Storage:																																	
Method	Dry																																
Hazard Class (Quantity-Distance)	Class 9																																
Compatibility Group	Group I Bureau of Explosives Class A																																
Heat of:																																	
Combustion, cal/gm	4392																																
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NFOC Pressure Cube	43																																
APG Blast Cube	53																																
Aviation Energy:																																	
kcal/mol	Values not included																																
Temp, °C	due to erratic igni-																																
Time to ignition, seconds	tion under conditions of test.																																

AMCP 706-177

MOX-6B

Composition:		Molecular Weight: 43	
%		Oxygen Balance:	
Oxidizing agent	----	CO ₂ %	-50
Aluminum, atomized	49.2	CO %	-42
Cupric Oxide	19.7	Density: gm/cc	
Magnesium, atomized	----	Melting Point: °C	
Other ingredients*	29.6	Freezing Point: °C	
Calcium Stearate	----	Boiling Point: °C	
Graphite, artificial	1.5	Refractive index, n_D²⁰	
*28.7% RDX coated, 0.9% wax.		n _D ²⁵	
C/H Ratio		n _D ³⁰	
Impact Sensitivity, 2 Kg Wt:		Vacuum Stability Test:	
Bureau of Mines Apparatus, cm	78	cc/40 Hrs, at	
Sample Wt 20 mg		90°C	----
Picatinny Arsenal Apparatus, in.	19	100°C	0.43
Sample Wt, mg	27	120°C	
		135°C	
		150°C	
Friction Pendulum Test:		200 Gram Bomb Sand Test:	
Steel Shoe	Unaffected	Sand, gm	10.8
Fiber Shoe	Unaffected	Sensitivity to Initiation:	
Rifle Bullet Impact Test:		Minimum Detonating Charge, gm	
Trials	%	Mercury Fulminate	----
Explosions		Lead Azide	0.20
Partials		Tetryl	0.16
Burned		Ballistic Mortar, % TNT:	
Unaffected		Trauzl Test, % TNT:	
Explosion Temperature: °C		Plate Dent Test:	
Seconds, 0.1 (no cap used)	---	Method	
1	---	Condition	
5	510	Confined	
10		Density, gm/cc	
15		Brisance, % TNT	
20		Detonation Rate:	
75°C International Heat Test:		Confinement	
% Loss in 48 Hrs	0.02/10 gm	Condition	
Discoloration, fumes, odor	None	Charge Diameter, in.	
100°C Heat Test:		Density, gm/cc	
% Loss, 1st 48 Hrs	0.00	Rate, meters/second	
% Loss, 2nd 48 Hrs	0.00		
Explosion in 100 Hrs	None		
Flammability Index:			
Hygroscopicity: %			
30°C, 90% RH, two weeks	0.79		
Volatility:			

MOX-6B

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

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MOX-1; MOX-2B; MOX-3B; MOX-4B; MOX-6BPreparation:

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 90°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 alcohol. After adding the ammonium perchlorate, the slurry 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.

MOX-1; MOX-2B; MOX-3B; MOX-4B; MOX-6B

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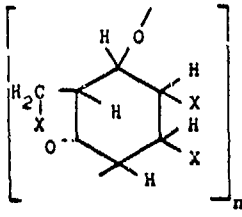
References:⁴⁶

- (a) A. C. 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. C. 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. C. 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 DAL-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.

⁴⁶See footnote 1, page 10.

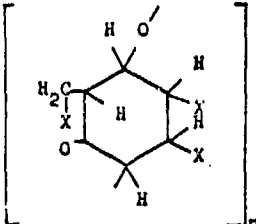
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Nitrocellulose, 12.6% N (NC)

Composition: % C 26.46 H 2.78 N 12.60 O 58.16 X=ONO ₂				Molecular Weight: (272.39) _n	
C/H Ratio 0.23		Oxygen Balance: CO ₂ % -35 CO % 0.6		Density: gm/cc	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 8 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		Melting Point: °C Decomposes		Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Boiling Point: °C		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 0.17 100°C 1.0 120°C 16 hours 11.4 135°C 150°C		200 Gram Bomb Sand Test: Sand, gm 45.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 170 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl		Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Troust Test, % TNT:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second			
Flammability Index:					
Hygroscopicity: % 30°C, 90% RH 3					
Volatility: 60°C, mg/cm ² /hr 0.0					

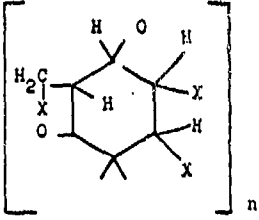
Nitrocellulose, 13.45% N (NC)

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

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Nitrocellulose, 14.14% N (NC)

Composition: % C 24.25 H 2.77 N 14.14 O 59.24 X=ONO ₂ C/H Ratio 0.23			
Impact Sensitivity, 2 Kg Wt: Bureau Mines Apparatus, cm 8 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5		Molecular Weight: (297.15) _n Oxygen Balance: CO ₂ % -24 CO % 8 Density, gm/cc 1.65-1.70 Melting Point: °C Decomposes Freezing Point: °C Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 1.46 100°C 14 hours 11.+ 120°C 16 hours 11.+ 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 52.3	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisanca, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, i Density, gm/cc Rate, meters/second	
Hygroscopicity: % 30°C, 90% RH ~ 1			
Volatility: 60°C, mg/cm²/hr 0.0			

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100. <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth <hr/> Color: White Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants						
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Loading 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	<div style="display: flex; justify-content: space-around;"> <div> Storage: Method Wet (8% to 30% water) Hazard Class (Quantity-Distance) Class 12 Compatibility Group Group K (wet) Exudation None </div> <div> Heat of: Combustion, cal/gm 2409* 2313** 2228*** Explosion, cal/gm 855* 965** 1058*** Gas Volume, cc/gm 919* 883** 853*** Formation, cal/gm 617* 561** 513*** * 12.6% N ** 13.45% N *** 14.14% N </div> </div> <div style="margin-top: 10px;"> Vapor Pressure: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center; width: 50%;"><u>°C</u></th> <th style="text-align: center; width: 50%;"><u>mm Mercury</u></th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">25</td> <td style="text-align: center;">0.00</td> </tr> <tr> <td style="text-align: center;">60</td> <td style="text-align: center;">0.00</td> </tr> </tbody> </table> </div>	<u>°C</u>	<u>mm Mercury</u>	25	0.00	60	0.00
<u>°C</u>	<u>mm Mercury</u>						
25	0.00						
60	0.00						

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Nitrocellulose (NC)

<u>Solubility in Water, gm/100 gm, at:</u>	<u>12.6% N</u>	<u>13.45% N</u>	<u>14.0% N</u>
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 + %)
Acetone	Soluble	Soluble	Soluble
<u>240-Hour Hydrolysis Test,</u> <u>% 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_2SO_4 63.5%, HNO_3 21%, H_2O 15.5%

b. for 13.4% N: H_2SO_4 68%, HNO_3 22%, H_2O 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_2SO_4 . 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)

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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 (1891-1895). This material, when colloided, formed the first smokeless powder for military use in the United States (1898).

Guncotton for military purposes today contains 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 13.15% 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:⁴⁷

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

⁴⁷See 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	653	394	1065	1066	1197	718	669
1150	1031	752	673	724	1125	1206	1267	758	709
1190	1041	802	683	804	1135	1256	1297	778	739
1210	1071	052	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	858	909
1320	1221	1142	1023	1074	1365	1516	1447	1058	1119
1350	1231	1242	1233	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	1663	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	1863	1394	1955		1847	1528	1439
1830	1541	1912	1873	1454			2107	1638	1449
1990	1681	1992	1973	1674			2137	1678	1619
2210	1691	2022		1754				1838	1799
	1731	2102		1814				1898	1809
	1781			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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Composition: % C 15.9 $\text{H}_2\text{C}-\text{ONO}_2$ H 2.2 $\text{HC}-\text{ONO}_2$ N 18.5 $\text{H}_2\text{C}-\text{ONO}_2$ O 63.4 C/H Ratio 0.109		Molecular Weight: $(\text{C}_3\text{H}_5\text{N}_3\text{O}_9)$ 227	
		Oxygen Balance: CO ₂ % 3.5 CO % 24.5	
		Density: gm/cc 25°C, Liquid 1.591 20°C, Liquid 1.596	
		Melting Point: °C Labile form 2.2 Stable form 13.2	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 1 lb wt 1 Sample Wt, mg		Boiling Point: °C Decomposes 145	
		Refractive Index, n_D^{20} 1.4732 n_D^{25} 1.4713 n_D^{30}	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe		Vacuum Stability Test: 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	
Rifle Bullet Impact Test: Trials % Explosions 100 Partial 0 Burned 0 Unaffected 0		200 Gram Bomb Sand Test: Sand, gm Liquid method 51.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 222 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Mortar, % TNT: (a) 140	
		Trausal Test, % TNT: (b) 181	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 3.6 % Loss, 2nd 48 Hrs 3.5 Explosion in 100 Hrs None		Detonation Rate: Confinement Glass Steel Condition Liquid Liquid Charge Diameter, in. 0.39 1.25 Density, gm/cc 1.6 1.6 Rate, meters/second 1600-1900 7700	
Flammability Index:			
Hygroscopicity: % 30°C, 90% RH 0.06			
Volatility: 60°C, mg/cm ² /hr 0.11			

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Nitroglycerin (Liquid)

Booster Sensitivity Test:		Decomposition Equation:	
Condition		Oxygen, atoms/sec	$10^{17.3}$ $10^{19.2}$
Tetryl, gm		(Z/sec)	
Wax, in. for 50% Detonation		Heat, kilocalorie/mole	41.4 45.0
Wax, gm		(ΔH , kcal/mol)	
Density, gm/cc		Temperature Range, °C	90-135 125-150
		Phase	Liquid Liquid
Heat of:		Armor Plate Impact Test:	
Combustion, cal/gm	1616	60 mm Mortar Projectile:	
Explosion, cal/gm	1600	50% Inert, Velocity, ft/sec	
Gas Volume, cc/gm	715	Aluminum Fineness	
Formation, cal/gm	400	500-lb General Purpose Bombs:	
Fusion, cal/gm		Plate Thickness, inches	
Detonation, cal/gm	1486	1	
Specific Heat: cal/gm/°C		1 1/4	
Liquid	0.356	1 1/2	
Solid	0.315	1 3/4	
Burning Rate:		Bomb Drop Test:	
cm/sec		77, 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, Mohs' Scale:		Low Order	
Young's Modulus:		High Order	
E', dynes/cm ²		1000-lb General Purpose Bomb vs Concrete:	
E, lb/inch ²		Height, ft	
Density, gm/cc		Trials	
Compressive Strength: lb/inch²		Unaffected	
Vapor Pressure:		Low 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)

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

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Nitroglycerin (Liquid)Gas Evolved at Atmospheric Pressure, cc:

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

Viscosity: (c)

<u>°C</u>	<u>Centipoises</u>
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)

<u>% Dimethylphthalate in NG</u>	<u>Min. Propagating Diameter, inches</u>	<u>Maximum Diameter for 2 Failures in 2 Trials, inches</u>
0	(3/16 Cairns)	1/16
5	--	1/8
10	1/8	3/16
15	1/4	3/8
20	3/4	7/8
22.5	1	1-1/2
25	1.55	2

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

Solubility, grams of nitroglycerin/100 gm (%) of:

<u>Water</u>		<u>Alcohol</u>		<u>Trichlorethylene</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>
15	0.16	0	37.5	Rm	22	Rm	2
20	0.18	20	54.0				
50	0.25						

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Nitroglycerin (Liquid)

<u>Carbon Disulfide</u>		<u>gm/100 gm (%), at 25°C in</u>	
<u>°C</u>	<u>g</u>		
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>DNT</u>		<u>TNT</u>		<u>Water</u>	
<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</u>	<u>°C</u>	<u>g</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.

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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 (Abel 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:⁴⁸

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

(b) Ph. Naoum, Z ges Schiess-Sprengstoffv, pp. 181, 229, 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	792	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
1210	1031	1282	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								

⁴⁸See footnote 1, page 10.

Nitroguanidine

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Composition: % C 11.5 H 3.9 N 53.8 O 30.8 C/H Ratio 0.038 <div style="text-align: center;"> $\begin{array}{c} \text{NH}_2 \\ \\ \text{HN}=\text{C} \\ \\ \text{NH} \\ \\ \text{NO}_2 \end{array}$ </div>		Molecular Weight: (CH ₂ N ₄ O ₂) 104	
		Oxygen Balance: CO ₂ % -31 CO % -15.4	
		Density: gm/cc Crystal 1.72	
		Melting Point: °C 232	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 47 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 26 Sample Wt, mg 7		Boiling Point: °C	
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: (e) Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.37 120°C 0.44 135°C 150°C	
Rifle Bullet Impact Test: 5 Trials (e) Explosions % 0 Portals 0 Burned 0 Unaffected 100		200 Grain Bomb Sand Test: Sand, gm 36.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 275 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs 0.04 100°C Heat Test: % Loss, 1st 48 Hrs 0.18 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None		Ballistic Mortar, % TNT: (a) 104	
		Treuzl Test, % TNT: (b) 101	
Flammability Index: Hygroscopicity: % 30°C, 90% RH None Volatility: None		Plate Dent Test: (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 95	
		Detonation Rate: (e) Confinement Condition Charge Diameter, in. Density, gm/cc 1.55 Rate, meters/second 7650	

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Nitroguanidine

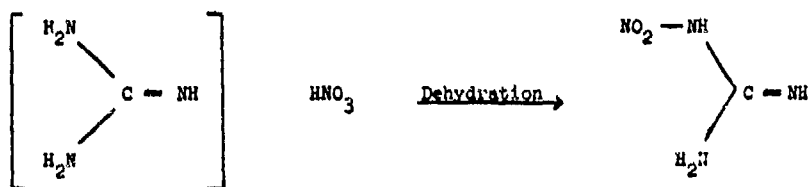
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Colorless Principal Uses: Propellant composition ingredient, bursting charge ingredient Method of Loading: Loading Density: gm/cc At 3000 psi 0.95 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation																																		
Fragment Velocity: ft/sec At 9 ft At 25 1/4 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	Solubility, gm/100 gm (%), in: <table><tr><td></td><td>°C</td><td>%</td></tr><tr><td>Water</td><td>25</td><td>0.44</td></tr><tr><td></td><td>100</td><td>9.0</td></tr><tr><td>1.0 N Potassium Hydroxide</td><td>25</td><td>1.2</td></tr><tr><td>40% Sulfuric Acid</td><td>0</td><td>3.4*</td></tr><tr><td></td><td>25</td><td>8.0*</td></tr></table> * gm/100 cc solution Booster Sensitivity Test: (d) <table><tr><td>Condition</td><td>Pressed</td></tr><tr><td>Tetryl, gm</td><td>100</td></tr><tr><td>Wax, in. for 50% Detonation</td><td>0.67</td></tr><tr><td>Density, gm/cc</td><td>1.41</td></tr></table> Heat of: <table><tr><td>Combustion, cal/gm</td><td>1995</td></tr><tr><td>Explosion, cal/gm</td><td>721</td></tr><tr><td>Gas Volume, cc/gm</td><td>1077</td></tr><tr><td>Formation, cal/gm</td><td>227</td></tr></table>		°C	%	Water	25	0.44		100	9.0	1.0 N Potassium Hydroxide	25	1.2	40% Sulfuric Acid	0	3.4*		25	8.0*	Condition	Pressed	Tetryl, gm	100	Wax, in. for 50% Detonation	0.67	Density, gm/cc	1.41	Combustion, cal/gm	1995	Explosion, cal/gm	721	Gas Volume, cc/gm	1077	Formation, cal/gm	227
	°C	%																																	
Water	25	0.44																																	
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Condition	Pressed																																		
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Density, gm/cc	1.41																																		
Combustion, cal/gm	1995																																		
Explosion, cal/gm	721																																		
Gas Volume, cc/gm	1077																																		
Formation, cal/gm	227																																		

Nitroguanidine

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Preparation:

(Chemistry of Powder and Explosives, Davis)



Four hundred gms 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:⁴⁹

- (a) L. C. Smith and E. G. Lyster, 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 Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Departments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

⁴⁹See footnote 1, page 10.

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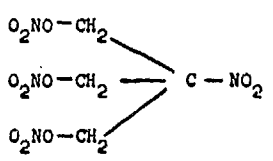
Nitroguanidine

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

<u>0</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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Composition: %			Molecular Weight: (C ₄ H ₆ N ₄ O ₁₁) 286	
C	16.8		Oxygen Balance:	
H	2.1		CO ₂ % 0.0	
N	19.6		CO % 22	
O	61.5			
C/H Ratio 0.126			Density: gm/cc 20°C 1.64	
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C	
Bureau of Mines Apparatus, cm 25				
Sample Wt 20 mg			Refractive Index, n_D²⁰	
Picatinny Arsenal Apparatus, in.			n _D ²⁰ 1.4896	
Sample Wt, mg			n _D ²⁰ 1.4874	
Friction Pendulum Test:			Vacuum Stability Test:	
Steel Shoe			cc/40 Hrs, at	
Fiber Shoe			90°C	
Rifle Bullet Impact Test: Trials			100°C	
Explosions %			120°C	
Partials			135°C	
Burned			150°C	
Unaffected			200 Gram Bomb Sand Test:	
Explosion Temperature: °C			Sand, gm 0.2 gm sample absorbed	
Seconds, 0.1 (no cap used)			by 0.2 gm of glassbeads 28	
1			Sensitivity to Initiation:	
5 Ignites 185			Minimum Detonating Charge, gm	
10			Mercury Fulminate	
15			Lead Azide	
20			Tetryl	
75°C International Heat Test:			Ballistic Mortar, % TNT:	
% Loss in 48 Hrs			Trauzl Test, % TNT:	
100°C Heat Test:			Plate Dent Test:	
% Loss, 1st 48 Hrs			Method	
% Loss, 2nd 48 Hrs			Condition	
Explosion in 100 Hrs			Confined	
Flammability Index:			Density, gm/cc	
Hygroscopicity: %			Brisance, % TNT	
Volatility:			Detonation Rate:	
25°C, mg/cm ² /24 hrs 0.127 x 10 ⁻³			Confinement Glass (1 mm wall)	
			Condition Liquid	
			Charge Diameter, in. 0.39	
			Density, gm/cc 1.64	
			Rate, meters/second 7860	

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Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

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

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 80°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 (60/38/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffv 7, 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:⁵⁰

- (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, Nitrocellulose 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 Sprengstoffv 37, 62-4 (1942); CA 38, 255 (1944).

⁵⁰See footnote 1, page 10.

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Nitrostarch Demolition Explosive (NSX)

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

Nitrostarch Demolition Explosive (NSX)

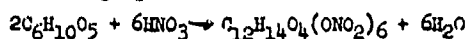
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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Demolition, bursting charges, and priming compositions
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Method of Loading: Hand tamped Loading Density: gm/cc Apparent 0.92 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	120°C Heat Test: <div style="display: flex; justify-content: space-between;"> <div> Salmon Pink Red Fumes Explodes </div> <div style="text-align: right;"> <u>Minutes</u> 70 255 256 </div> </div>

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Nitrostarch Demolition Explosive (NSX)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_3 and 37%-38% H_2SO_4) 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] 52, 290 (1833)). T. J. Pelouze studied xyloidine further and reported its explosive properties (Compt rend [7, 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: 51

(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:

<u>1</u>	<u>2</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1611	782	1034	1117	838	1269
	2032			848	

⁵¹See footnote 1, page 10.

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Octol, 70/30

Composition:		Molecular Weight: 265	
%		Oxygen Balance:	
HMX	70	CO ₂ %	-38
TNT	30	CO %	-7.5
C/H Ratio		Density: gm/cc	Cast 1.80
Impact Sensitivity, 2 Kg Wt:		Melting Point: °C	
Bureau of Mines Apparatus, cm		Freezing Point: °C	
Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.		Refractive Index, n_D²⁰	
Sample Wt, mg		n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
Rifle Bullet Impact Test: Trials		100°C	----
% Explosions		120°C	0.37
Partial		135°C	
Burned		150°C	
Unaffected		200 Gram Bomb Sand Test:	
Explosion Temperature: °C		Sand, gm	Exploratory 58.4
Seconds, 0.1 (no cap used)	---	Sensitivity to Initiation:	
1	---	Minimum Detonating Charge, gm	
5	Flames erratically 335	Mercury Fulminate	----
10		Lead Azide	0.30
15		Tetryl	----
20		Ballistic Mortar, % TNT:	
75°C International Heat Test:		115	
% Loss in 48 Hrs		Tensile Test, % TNT:	
100°C Heat Test:		Plate Dent Test:	
% Loss, 1st 48 Hrs		Method	
% Loss, 2nd 48 Hrs		Condition	
Explosion in 100 Hrs		Confined	
Flammability Index:		Density, gm/cc	
Hygroscopicity: %		Brisance, % TNT	
Volatility:		Detonation Rate:	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.80
		Rate, meters/second	8377

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Octol, 70/30

Booster Sensitivity Test: Condition Tetrl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2722 Explosion, cal/gm 1074 Gas Volume, cc/gm 847 Formation, cal/gm ---- Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 1510 See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch ² * Average (10 tests) 1510 High 1740 Low 1330	Ultimate Deformation: % 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 (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Octol, 70/30

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Colors: Buff Principal Uses: HE projectile and bomb filler Method of Loading: Cat
Fragment Velocity: ft/sec: At 9 ft At 25½ ft Density, gm/cc	Leading Density: gm/cc 1.80 Storage: Method Dry
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Work to Produce Rupture: ft-lb/inch³ * <div style="display: flex; justify-content: space-between;"> <div>Average (10 tests)</div> <div>1.55</div> </div> <div style="display: flex; justify-content: space-between;"> <div>High</div> <div>1.87</div> </div> <div style="display: flex; justify-content: space-between;"> <div>Low</div> <div>1.10</div> </div> Efflux Viscosity, Saybolt Seconds: 5.9 <p>*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.</p>

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Octol, 70/30

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

<u>Explosive</u>	<u>Simulated Altitude, Feet</u>	<u>One-Inch Column</u>		<u>Two-Inch Column</u>	
		<u>Confined</u>	<u>Unconfined</u>	<u>Confined</u>	<u>Unconfined</u>
		<u>m/s</u>	<u>m/s</u>	<u>m/s</u>	<u>m/s</u>
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	7830	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)

<u>Explosive</u>	<u>Charge Diameter, Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground</u>	<u>30,000</u>	<u>60,000</u>	<u>90,000</u>
		<u>m/s</u>	<u>m/s</u>	<u>m/s</u>	<u>m/s</u>
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 ²
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 ²
Average (10 tests)	73,200
High	79,300
Low	63,000

*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	92,000 psi*
Density, g/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	..
750 - 2500	12
Total Number	4467

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Octol, 75/25

Composition: % HMX 75 TNT 25 C/H Ratio	Molecular Weight: 276	
	Oxygen Balance: CO ₂ % -35 CO % -6.3	
	Density: gm/cc	Cast 1.81
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picotiny Arsenal Apparatus, in. 17 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
	Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	
Rifle Bullet Impact Test: 10 Trials % 2/16" Steel 1/8" Al Explosions 70 70 Partials -- -- Burned -- -- Unaffected 30 30	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C ---- 120°C 0.39 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm Exploratory 62.1	
	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 Flames erratically 350 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
	Ballistic Mortar, % TNT: 116	
75°C International Heat Test: % Loss in 48 Hrs	Treuzl Test, % TNT:	
	Plate Dust Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.81 Rate, meters/second 8643	
	Flammability Index:	
Hygroscopicity: %		
Volatility:		

Octol, 75/25

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Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2676 Explosion, cal/gm 1131 Gas Volume, cc/gm 830 Formation, cal/gm Fusion, cal/gm 29.4* *Calculated for 76.9% HMX, 23.1% TNT.	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C ** -79°C 0.200 -80°C to +80°C 0.240 33°C to 74°C 0.245 90°C to 150°C 0.323 **Determined for 76.9% HMX, 23.1% TNT.	Bomb Drop Test: 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
Burning Rate: cm/sec	Ultimate Deformation: % Average (10 tests) 2.43 High 2.89 Low 2.04
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch² 1340 See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch² *** Average (10 tests) 1340 High 1560 Low 1040	

***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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Octol, 75/25

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Buff Principal Uses: HE projectile and bomb filler Method of Loading: Cast Loading Density: gm/cc 1.81
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Work to Produce Rupture: ft-lb/inch³ * <div style="display: flex; justify-content: space-between;"> Average (10 tests) 1.31 </div> <div style="display: flex; justify-content: space-between;"> High 1.57 </div> <div style="display: flex; justify-content: space-between;"> Low 1.07 </div> Efflux Viscosity, Saybolt Seconds: 9.0 <p>*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.</p>

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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 ²
Average (10 tests)	266
High	330
Low	226

*Test specimen as per Picatinny Arsenal sketch XI-G76B, at 21°C.

Modulus of Elasticity:*

	lb/inch ²
Average (10 tests)	62,100
High	75,900
Low	45,200

*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

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Octol, 70/30; Octol, 75/25Preparation:

Water-wet HMX 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:⁵²

(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 DAF-19-020-501-ORD-(P)-58).

⁵²See footnote 1, page 10.

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PB-RDX

Booster Sensitivity Test: Condition Tetrayl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 3027 Explosion, cal/gm 983 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Init., Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C	Bomb Drop Tests: 57, 2000-lb Semi-Armor-Piercing 7 mil 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: See below E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 2403 2149 Percent 8.9 13.1	
Vapor Pressure: °C mm Mercury Young's Modulus: * (a) <u>Temperature</u> Ambient 95°C E, lb/inch ² (avg of 5) 39,953 34,831 Density, gm/cc 1.60 1.57	

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

PB-RDX

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Gloss Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: High mechanical strength explosive Method of Loading: Pressed																											
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Loading Density: gm/cc Pressed, psi x 10³ <div style="display: flex; justify-content: space-around;"> 0 10 20 30 </div> 1.10 1.49 1.59 1.62																											
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method: Dry Hazard Class (Quantity-Distance): Class 9 Compatibility Group: Group I Exudation: None Rockwell Hardness, "R" Scale: (a) 1/2 inch diameter Penetrator, 60 Kg Load: <table border="1" style="width: 100%;"> <thead> <tr> <th>Pellet No.*</th> <th>Specific Gravity</th> <th>Hardness</th> </tr> </thead> <tbody> <tr><td>1</td><td>1.624</td><td>84</td></tr> <tr><td>2</td><td>1.623</td><td>90</td></tr> <tr><td>3</td><td>1.611</td><td>84</td></tr> <tr><td>4</td><td>1.600</td><td>80</td></tr> <tr><td>5</td><td>1.590</td><td>75</td></tr> <tr><td>6</td><td>1.571</td><td>73</td></tr> <tr><td>7</td><td>1.548</td><td>62</td></tr> <tr><td>8</td><td>1.524</td><td>49</td></tr> </tbody> </table> *Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.	Pellet No.*	Specific Gravity	Hardness	1	1.624	84	2	1.623	90	3	1.611	84	4	1.600	80	5	1.590	75	6	1.571	73	7	1.548	62	8	1.524	49
Pellet No.*	Specific Gravity	Hardness																										
1	1.624	84																										
2	1.623	90																										
3	1.611	84																										
4	1.600	80																										
5	1.590	75																										
6	1.571	73																										
7	1.548	62																										
8	1.524	49																										

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PB-RDXSensitivity 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	1	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	0.084	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	5	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 ML 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. Teteryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 10⁶ 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.

PB-RDX

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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 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

Through U. S. Standard Sieve No.	Minimum %	Maximum %
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 H₂O (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

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PB-RDX

Commission, Report No. LA-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-1088, 25 October 1956.

References:⁵³

- (a) P. 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 ML 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 M307A1 (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project DA3-5204, October 1957.

⁵³See footnote 1, page 10.

Pentaerythritol Trinitrate (PETRIK)

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

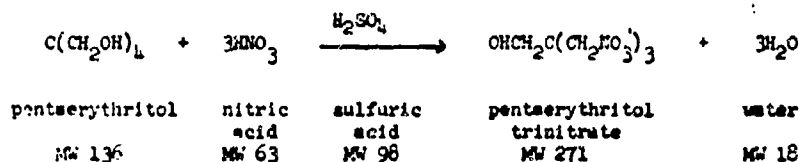
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Pentaerythritol Trinitrate (PETRIN)

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Color: White
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Absolute Viscosity, poises: <div style="display: flex; justify-content: space-between;"> <div> Temp, 17°C 23°C 28°C 38°C </div> <div> 14.3 4.8 3.0 1.2 </div> </div>	Principal Uses: Explosive, propellant or igniter ingredient
	Method of Loading:
	Loading Density: gm/cc
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Eruption None
	<p>PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.</p> <p>An infrared spectrophotometric procedure was developed for the determination of the acetone content of PETRIN (ref c). A 2.5 gm sample of PETRIN is dissolved in chloroform and the volume increased to 25 milliliters in a volumetric flask. The acetone content of the PETRIN solution is determined by its infrared absorption at 5.82μ in a 0.5 mm cell. A double beam method is used with a reference cell containing chloroform and acetone-free PETRIN. The quantity of the latter must be carefully adjusted to give a good balance between the test sample and reference cells for the strong PETRIN peak at 6.02μ maximum.</p> <p>Heat of: Explosion, cal/gm 1204 </p>

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% HNO₃ and the solid pentaerythritol were charged to the reactor and 80% H₂SO₄ 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 PETN 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. Methylene 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, PETN must 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 NO₂ groups were patented for use as explosives, propellants or ignition materials in 1936 (German Patents 635,432 and 635,433; 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% HNO₃ and 80% H₂SO₄ 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:⁵⁴

- (a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Trinitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 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 NOTS 1877, NAVORD Report No. 5649, 3 February 1958.

⁵⁴See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate)
(Trinitropentaerythritol Acrylate)

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Composition: % C 29.5 H 3.4 N 12.9 O 54.2 C/H Ratio 0.239	Molecular Weight: (C ₈ H ₁₁ N ₃ O ₁₁) 325 Oxygen Balance: CO ₂ % -54 CO % -12 Density: gm/cc Melting Point: °C 78 to 79 Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Grain Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Master, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Treacal Test, % TNT:
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Hygroscopicity: % N11	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Volatility:	

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Pentaerythritol Trinitroacrylate (PETRIN Acrylate)

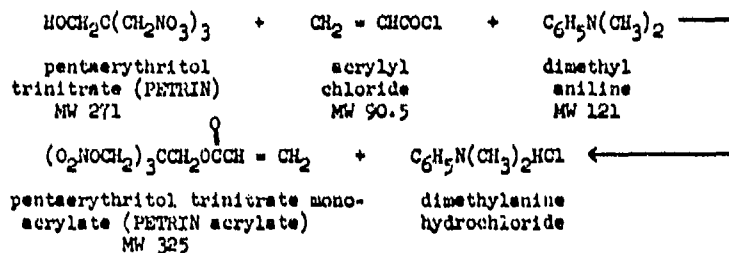
Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness: TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth:</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth:		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth:										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: White									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Ingredient of composite rocket propellants									
	Method of Loading:									
	Loading Density: gm/cc									
	Storage: Method Dry at temperatures below melting point Hazard Class (Quantity-Distance) Compatibility Group Exudation None									
	Heat of: <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2923</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>791</td> </tr> </table>	Combustion, cal/gm	2923	Explosion, cal/gm	791					
Combustion, cal/gm	2923									
Explosion, cal/gm	791									

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:⁵⁵

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

⁵⁵See footnote 1, page 10.

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Pentolite, 50/50; 10/90

Composition: % PETN 50 10 TNT 50 90 C/H Ratio	Molecular Weight: <u>50/50</u> <u>10/90</u> 265 234	
	Oxygen Balance: CO ₂ % -42 -68 CO % - 5 -21	
	Density: gm/cc 1.65 1.60	
	Melting Point: °C 76	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: <u>50/50</u> <u>10/90</u> Bureau of Mines Apparatus, cm 34 65 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 12 14 Sample Wt, mg 15 18	Boiling Point: °C	
	Refractive Index, n_D n _D n _D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: <u>50/50</u> <u>10/90</u> cc/40 Hrs, at 90°C	
	100°C 3.0 3.0	
Rifle Bullet Impact Test: 25 Trials, 50/50 Explosions % 72 Partial 20 Burned 0 Unaffected 8	120°C 11+ 11+	
	135°C -- --	
	150°C -- --	
	200 Grain Bomb Sand Test:	
	Sand, gm 55.6 49.5	
Explosion Temperature: °C, 50/50 Seconds, 0.1 (no cap used) 290 1 266 5 Decomposes 220 10 204 15 197 20 >190	Sensitivity to Initiation: <u>50/50</u> Minimum Detonating Charge, gm Mercury Fulminate 0.19* Lead Azide 0.13* Tetryl -- *Alternative initiating charges.	
	Ballistic Mortar, % TNT: (a) 126	
	Trauzl Test, % TNT: (b) 122	
	Plate Dent Test: (c)	
	Method B	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: <u>50/50</u> % Loss, 1st 48 Hrs 0.0 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None	Condition Cast	
	Confined No	
	Density, gm/cc 1.66	
	Brisance, % TNT 121	
Flammability Index: Will not continue to burn	Detonation Rate:	
	Confinement None	
Hygroscopicity: % 30°C, 90% RH <u>50/50</u> <u>10/90</u> None None	Condition Cast	
	Charge Diameter, in. 1.0	
Volatility:	Density, gm/cc 1.66	
	Rate, meters/second 7465	

Pentolite, 50/50; 10/90

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Booster Sensitivity Test: (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	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm 1220 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: <u>50/50</u> 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 170 Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ² 2000-2200 Density, gm/cc 1.68	
Vapor Pressure: °C mm Mercury	

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Pentolite, 50/50; 10/90

Fragmentation Test:		<u>50/50</u>	Shaped Charge Effectiveness, TNT = 100:				
90 mm HE, M71 Projectile, Lot WC-91:			<u>50/50</u>	<u>10/90</u>	<u>50/50</u>	<u>25/75</u>	
Density, gm/cc		1.65	Glass Cones (f) Steel Cones (g)				
Charge Wt, lb		2.1	Hole Volume	157	105	149	119
			Hole Depth	116	116	131	119
Total No. of Fragments:			Color:				Yellow-white
For TNT		703	Principal Uses:				Shaped charges, bursting charges, demolition blocks
For Subject HE		968	Method of Loading:				Cast
3 inch HE, M42A1 Projectile, Lot KC-3:			Loading Density: gm/cc				<u>50/50</u> <u>10/90</u>
Density, gm/cc		1.65					1.65 1.60
Charge Wt, lb		0.872	Storage:				
Total No. of Fragments:			Method				Dry
For TNT		514	Hazard Class (Quantity-Distance)				Class 9
For Subject HE		650	Compatibility Group				Group I
Fragment Velocity: ft/sec			Exudation				
At 9 ft		2810	Compatibility with Metals:				
At 25 1/4 ft		2580	<u>Dry:</u> 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.				
Density, gm/cc		1.66	<u>Wet:</u> 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.				
Blast (Relative to TNT):		(e)	Effect of Temperature on				(h)
Air:			Rate of Detonation:				
Peak Pressure		105	16 hrs at, °C				<u>50/50</u>
Impulse		107	Density, gm/cc				-54 21
Energy		--	Rate, m/sec				1.67 1.66
Air, Confined:							7470 7440
Impulse							
Under Water:							
Peak Pressure							
Impulse							
Energy							
Underground:							
Peak Pressure							
Impulse							
Energy							
Eutectic Temperature, °C:		76					
gm PETN/100 gm TNT							
76°C		13.0					
95°C		29.3					

Pentolite, 50/50; 10/90

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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:⁵⁶

(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 Teteryl in Boosters, NOL Memo 10,303, 15 June 1949.

(e) W. R. Tomlinson, Jr., Blunt 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 W672-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 1936.

(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

⁵⁶See footnote 1, page 10.

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PETN (Pentaerythritol Tetranitrate)

Composition: %			Molecular Weight: (C ₅ H ₈ N ₄ O ₁₂) 316	
C	19.0	<div>ONO₂ CH₂ O₂HO-CH₂-C-CH₂-ONO₂ CH₂ ONO₂</div>	Oxygen Balance:	
H	2.5		CO ₂ % -10	
N	17.7		CO % 15	
O	60.8		Density: gm/cc Crystal 1.77	
C/H Ratio	0.134		Melting Point: °C 141	
Impact Sensitivity, 2 Kg Wt:			Freezing Point: °C	
Bureau of Mines Apparatus, cm 17			Boiling Point: °C	
Sample Wt 20 mg			Refractive Index, n_D²⁰	
Picatinny Arsenal Apparatus, in. 6			n _D ²⁵	
Sample Wt, mg 16			n _D ³⁰	
Friction Pendulum Test:				
Steel Shoe		Crackles		
Fiber Shoe		Unaffected		
Rifle Bullet Impact Test: 5 Trials *				
Explosions		%		
Partial		0		
Burned		0		
Unaffected		0		
*4.8% moisture in samples				
Explosion Temperature: °C				
Seconds, 0.1 (no cap used)		272		
1		244		
5 Decomposes		225		
10		211		
15		--		
20		--		
75°C International Heat Test:				
% Loss in 48 Hrs		0.02		
100°C Heat Test:				
% Loss, 1st 48 Hrs		0.1		
% Loss, 2nd 48 Hrs		0.0		
Explosion in 100 Hrs		None		
Flammability Index: Will not continue to burn				
Hygroscopicity: % 30°C, 90% RH 0.0				
Volatility: 0.0				
Vacuum Stability Test:				
cc/40 Hrs, at				
90°C				
100°C 0.5				
120°C 11+				
135°C				
150°C				
200 Gram Bomb Sand Test:				
Sand, gm		62.7		
Sensitivity to Initiation:				
Minimum Detonating Charge, gm				
Mercury Fulminate		0.17*		
Lead Azide		0.03*		
Tetryl		--		
*Alternative initiating charges.				
Ballistic Mortar, % TNT: (a) 145				
Treuzl Test, % TNT: (b) 173				
Plate Dent Test: (c)				
Method		A		
Condition		Pressed		
Confined		Yes		
Density, gm/cc		1.50		
Brisance, % TNT		129		
Detonation Rate:				
Confinement		None		
Condition		Pressed		
Charge Diameter, in.		1.00		
Density, gm/cc		1.70		
Rate, meters/second		8300		

PEIN (Pentaerythritol Tetranitrate)

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Booster Sensitivity Test: Condition (c) Pressed Tetryl, gm 5 Wax, in. for 50% Detonation Wax, gm 3 Density, gm/cc 1.6	Decomposition Equation: (e) (e) (f) Oxygen, atoms/sec $10^{19.8}$ $10^{20.6}$ $10^{23.1}$ (Z/sec) Heat, kilocalorie/mole 47.0 50.9 52.3 (ΔH , kcal/mol) Temperature Range, °C 161-233 108-120 137-157 Phase Liquid Solid At melting point
Heat of: Combustion, cal/gm 1960 Explosion, cal/gm 1385 Gas Volume, cc/gm 790 Formation, cal/gm 383 Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (d) Room Temperature 0.26	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm² °C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale: 1.9	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: °C mm Mercury	

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PETN (Pentaerythritol Tetranitrate)

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Color: White
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Class A - Detonating fuse and boosters Class B - Priming compositions
	Method of Loading:
	Loading Density: gm/cc psi x 10³ 3 5 10 20 30 40 1.37 1.58 1.64 1.71 1.73 1.74
	Storage: Method Wet Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation None
	Bulk Modulus at Room Temperature (25°-30°C): (1) Dynes/cm ² x 10 ⁻¹⁰ 4.60 Density, gm/cc 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 (%) of: (h)Trichlorethylene
or Alcohol

<u>°C</u>	<u>%</u>
0	0.070
20	0.195
40	0.415
60	1.205

Acetone

<u>°C</u>	<u>%</u>
0	14.37
20	24.95
40	30.56
60	42.68

Benzene

<u>°C</u>	<u>%</u>
0	0.150
20	0.450
40	1.160
80	7.900

Toluene

<u>°C</u>	<u>%</u>
0	0.150
20	0.430
40	0.620
60	2.490
80	5.850
100	15.920
112	30.900

Methyl acetate

<u>°C</u>	<u>%</u>
20	13
30	17
40	22
50	31

Ether

<u>°C</u>	<u>%</u>
0	0.200
20	0.340
34.7	0.450

p-Ethoxy-ethyl-
acetate

<u>°C</u>	<u>%</u>
20	1.5
30	4.1
40	7.6
50	11.2
60	14.2

Chlorobenzene

<u>°C</u>	<u>%</u>
20	0.35
30	2.8
40	6.1
50	9.2
60	12.2

Ethylendichloride

<u>°C</u>	<u>%</u>
10	0.9
30	1.5
50	2.6

Methanol

<u>°C</u>	<u>%</u>
20	0.46
40	1.15
60	2.6

Tetrachloroethane

<u>°C</u>	<u>%</u>
20	0.18
30	0.27
40	0.40
50	0.58

Carbon
tetrachloride

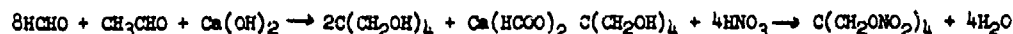
<u>°C</u>	<u>%</u>
20	0.096
30	0.103
40	0.118
50	0.121

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PETN (Pentaerythritol Tetranitrate)

Isopropanol		Isobutanol		Chloroform		TNT	
°C	%	°C	%	°C	%	°C	%
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	87.8
						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, Naoum)

1. In this preparation 1940 gm of formaldehyde and 600 gm of acetaldehyde 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 - Sprengstoff 11, 121, 182 (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:⁵⁷

(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 - Sprengstoff, 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.

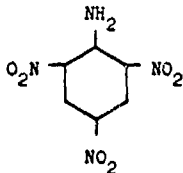
(j) Also see the following Picatinny Arsenal Technical Reports on PETN:

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	1325	1276	527	832	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	1598	
1380		1352	1533			1556	1797	1838	
1390		1372				1796		2178	
1430		1452							
1450									
1570									

⁵⁷See footnote 1, page 10.

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Picramide (TNA) (2,4,6-Trinitroaniline)

Composition: % C 31.5 H 1.8 N 24.5 O 42.2 C/H Ratio 0.500				Molecular Weight: (C ₆ H ₄ N ₄ O ₆) 228
		Oxygen Balance: CO ₂ % -56 CO % -14		
		Density: gm/cc Crystal 1.76		
		Melting Point: °C 189 to 190		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 23 Sample Wt, mg 20		Boiling Point: °C Decomposes before boiling point		
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰		
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.9 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Grain Bomb Sand Test: Sand, gm 48.1		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----		
		Ballistic Mortar, % TNT: 100		
75°C International Heat Test: % Loss in 48 Hrs		Trauzl Test, % TNT: 107		
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.72 Rate, meters/second 7300		
Hygroscopicity: %				
Volatility:				

Picramide (TNA) (2,4,6-Trinitroaniline)

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Yellow Principal Uses: High temperature heat resistant explosive Method of Loading: Pressed Loading Density: gm/cc At 50,000 psi 1.72 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None		
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	Solubility: Insoluble in water, slightly soluble in alcohol and ether. Soluble in hot glacial acetic acid, hot ethyl acetate and in benzene and acetone. Heat of: Combustion, cal/gm (a) 2962 Explosion, cal/gm 564 Formation, cal/gm (a) 131		

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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 78% yield (3.6 gm) melting at 190°C (literature MP 189°C).

Origin:

Picramide (2,4,6-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with ammonium carbonate (CR 32, 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 H₂SO₄ at about 5°C with concentrated HNO₃ (Ber 41, 3091 (1908)). Holleman gives details of the preparation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference:⁵⁸

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

⁵⁸See footnote 1, page 10.

Picratol, 52/48

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Composition: % Explosive D 52 TNT 48 C/H Ratio	Molecular Weight: 236	
	Oxygen Balance: CO ₂ % -63 CO % -19	
	Density: gm/cc	Cast 1.62
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
	Vacuum Stability Test:	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	cc/40 Hrs, -:	
	90°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partials 0 Burned 40 Unaffected 60	100°C	0.37
	120°C	0.68
	135°C	--
	150°C	0.7
	200 Gram Bomb Sand Test:	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 456 1 354 5 Decomposes 285 10 265 15 260 20 255	Sand, gm 45.0	
	Sensitivity to Initiation:	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	
	Lead Azide	0.20
	Tetryl	0.05
75°C International Heat Test: % Loss in 48 Hrs 0.0	Ballistic Meter, % TNT: (a) 100	
	Tensile Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.0 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Plate Dent Test: (b)	
	Method	B
	Condition	Cast
	Confined	No
Flammability Index:	Density, gm/cc	1.63
	Brisance, % TNT	100
Hygroscopicity: % 30°C, 90% RH 0.02	Detonation Rate: (b)	
	Confinement	None
Volatility:	Condition	Cast
	Charge Diameter, in.	1.0
	Density, gm/cc	1.63
	Rate, meters/second	6976

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Picratol, 52/48

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb 2.075 Total No. of Fragments: For TNT 703 For Subject HE 769 3 inch HE, M2A1 Projectile, Lot KC-3: Density, gm/cc 1.61 Charge Wt, lb 0.850 Total No. of Fragments: For TNT 514 For Subject HE 487	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Brown-yellow Principal Uses: AP, SAP projectiles and bombs Method of Loading: Cast Loading Density, gm/cc 1.62 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C <u>Preparation:</u> 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. <u>Origin:</u> Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler <u>Booster Sensitivity Test:</u> (c) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.00 Density, gm/cc 1.63
Fragment Velocity: ft/sec At 9 ft 2590 At 25½ ft 2320 Density, gm/cc 1.62	
Shock (Relative to TNT): Air: Peak Pressure 100 Impulse 100 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Bomb Drop Test:</u> T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 10,000-12,000	

Picratol, 52/48

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References:⁵⁹

(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:

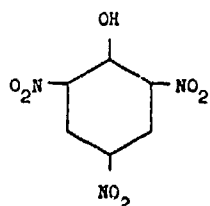
<u>0</u>	<u>2</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1470	1885	1466	1737	1838	1729
		1796	1797		
		1956			

⁵⁹See footnote 1, page 10.

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Picric Acid

Composition: % C 31.5 H 1.3 N 18.3 48.9 C/H Ratio 0.656		Molecular Weight: $(C_6H_3N_3O_7)$ 229 Oxygen Balance: CO ₂ % -45 CO % -3.5 Density: gm/cc Crystal 1.76 Melting Point: °C 122 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 85 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17		Boiling Point: °C Refractive Index, n_{20}^D n_{20}^D n_{20}^D	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.5 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 60 Burned 40 Unaffected 0		200 Gram Bomb Sand Test: Sand, gm 48.5	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 320 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.26* Lead Azide 0.24* Tetryl *Alternative initiating charges.	
75° C International Heat Test: % Loss in 48 Hrs 0.05		Ballistic Mortar, % TNT: (a) 112 Treuzl Test, % TNT: (b) 101	
100° C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None		Plate Dent Test: (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 107	
Flammability Index:		Detonation Rate: (d) Confinement Unconfined Condition Pressed Cast Charge Diameter, in. 1.0 1.25 Density, gm/cc 1.64 1.71 Rate, meters/second 5270 7350	
Hygroscopicity: % 30°C, 90% RH 0.04			
Volatility:			



Picric Acid

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Booster Sensitivity Test:			Decomposition Equation:		
Condition	Pressed	Cast	Oxygen, atoms/sec		
Tetryl, gm	10	5	(Z/sec)		
Wax, in. for 50% Detonation			Heat, kilocalorie/mole		
Wax, gm	2	0	(ΔH , kcal/mol)		
Density, gm/cc	1.6	1.7	Temperature Range, °C		
			Phase		
Heat of:			Armor Plate Impact Test:		
Combustion, cal/gm	2672		60 mm Mortar Projectile:		
Explosion, cal/gm	1000		50% Inert, Velocity, ft/sec		
Gas Volume, cc/gm	675		Aluminum Fineness		
Formation, cal/gm	248		500-lb General Purpose Bombs:		
Fusion, cal/gm (e)	20.4		Plate Thickness, inches		
Temperature, °C	122		1		
Specific Heat: cal/gm/°C (e)			1 1/4		
0	0.235		1 1/2		
30	0.258		1 3/4		
60	0.282				
90	0.310				
120	0.337				
Burning Rate:			Bomb Drop Test:		
cm/sec			T7, 2000-lb Semi-Armor-Piercing Bomb vs. Concrete:		
Thermal Conductivity: (f)			Max Safe Drop, ft		
cal/sec/cm/°C	6.24 x 10 ⁻⁴		500-lb General Purpose Bomb vs Concrete:		
Density, gm/cc	1.406		Height, ft		
Coefficient of Expansion:			Trials		
Linear, %/°C			Unaffected		
Volume, %/°C			Low Order		
Hardness, Mohs' Scale:			High Order		
	2.1		1000-lb General Purpose Bomb vs Concrete:		
Young's Modulus:			Height, ft		
E', dynes/cm ²			Trials		
E, lb/inch ²			Unaffected		
Density, gm/cc			Low Order		
Compressive Strength: lb/inch²			High Order		
Vapor Pressure:					
°C	mm Mercury				
195	2				
255	50				

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Picric Acid

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Yellow Principal Uses: Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Method of Loading: Pressed Loading Density: gm/cc psi x 10 ³ <div style="display: flex; justify-content: space-around;"> <div>3 5 10</div> <div>12 15 20</div> </div> <div style="display: flex; justify-content: space-around;"> 1.40 1.50 1.57 1.59 1.61 1.64 </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method: Dry Hazard Class (Quantity-Distance): Class 9 Compatibility Group: Group I Exudation: None

Picric Acid

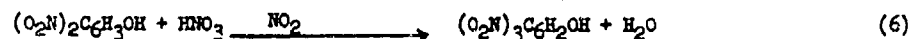
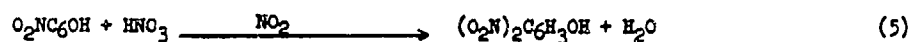
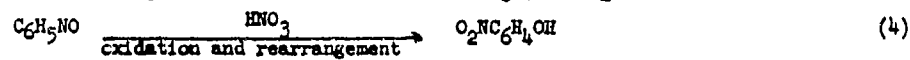
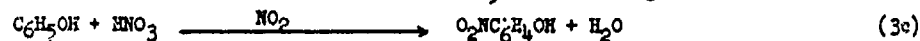
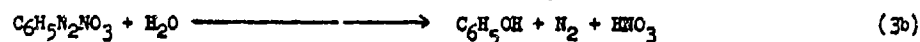
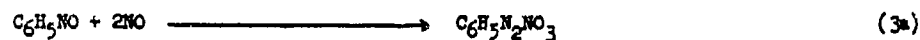
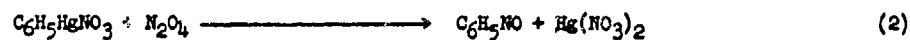
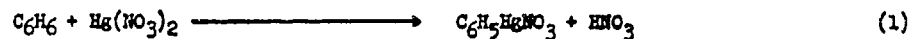
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Solubility: grams per 100 grams (%) of: (g)

<u>Water</u>		<u>Alcohol</u>		<u>Benzene</u>		<u>Toluene</u>		<u>Ether</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.85	0	4.5	0	~2	20	~13	20	~3
20	1.17	20	6.9	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>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	~2	20	42	20	~0.07	10	24	20	125
60	~5	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>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</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 NDRG, Div 8, Vol I)

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Picric Acid

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 nitrophenols and amounts 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 0.37 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 Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmann isolated Picric Acid in 1778 and studied it further (Journal de physique 32, 165 (1788)). The preparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim phys III, 3, 221 (1841)). It was used as a yellow dye until Turpin, in 1885, 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 1882 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 ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

Picric Acid

AMCP 706-177

References:⁶⁰

(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-Sprengstoff, 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. Hurritz, 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:

<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>
1651	132	1383	694	65	266	1347	1118	1549
	582		764	425	556	1557		
	1172		874	1585	926			
	1352				976			
	1372				986			
					1446			
					1556			

⁶⁰See footnote 1, page 10.

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PIPE

Composition: % PETN 81 Gulf Crown E Oil 19 C/H Ratio	Molecular Weight: 310	
	Oxygen Balance: CO ₂ % -74 CO % -31	
	Density: gm/cc	Hand tamped 1.35
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg 11 Picatinny Arsenal Apparatus, in. Sample Wt, mg 27	Boiling Point: °C	
	Refractive Index, n_D n _D n _D	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.48 120°C 16 hours 11+ 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 41.6	
Rifle Bullet Impact Test: Trials Explosions % 0 Partials 0 Burned 0 Unaffected 100	Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes* 10 15 20 *No value obtained.	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20* Lead Azide 0.20* Tetryl *Alternative initiating charges.	
	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 0.17 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Plate Dent Test: (a) Method B Condition Hand tamped Confined No Density, gm/cc 1.33 Brisance, % TNT 76	
	Detonation Rate: Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.37 Rate, meters/second 7075	
	Flammability Index:	
	Hygroscopicity: % 30°C, 90% RH 0.02	
	Volatility:	

PIPE

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.33 Charge Wt, lb 1.723 Total No. of Fragments: For TNT 703 For Subject HE 519 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.39 Charge Wt, lb 0.735 Total No. of Fragments: For TNT 514 For Subject HE 428	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: Plastic demolition explosive
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Method of Loading: Hand tamped Loading Density: gm/cc 1.35
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Preparation: PIPE is manufactured by simple mechanical mixing of PETN in oil.	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Origin: PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United States during World War II. References: 61 (a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests: Performance Tests</u> , OSRD Report No. 5746, 27 December 1945. (b) S. Livingston, <u>Properties of Explosives RIPE, PIPE and PEP-3</u> , Picatinny Arsenal Technical Report 1517, 24 April 1945.

61See footnote 1, page 10.

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Plumbatol

Composition: % Lead Nitrate 70 TNT 30 C/H Ratio	Molecular Weight: 291	
	Oxygen Balance: CO ₂ % -5.4 CO % +9.3	
	Density: gm/cc	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 22	Boiling Point: °C	
	Refractive Index: n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 32.4	
	Sensitivity to Initiators: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.10	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 238 10 15 20	Ballistic Mortar, % TNT:	
	Treuzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brissance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: (b) Confinement Condition Charge Diameter, in. Density, gm/cc 2.89 Rate, meters/second 4850	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Plumbetol

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones (a) Hole Volume 114 Hole Depth 103 Color: Light yellow Principal Uses: Method of Loading: Cast Loading Density: gm/cc Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Origin: An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Marcarite." References: ⁶² (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>Thorpe's Dictionary of Applied Chemistry</u> , Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy <u>Preparation:</u> Plumbetol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.	

⁶²See footnote . page 10.

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PLX (Liquid)

Composition:			Molecular Weight:	
%		*	<u>100</u>	<u>95/5</u>
Nitromethane	100	95	<u>61</u>	<u>61</u>
Ethylenediamine	--	5	Oxygen Balance:	
*The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under <u>Storage</u> .			CO ₂ %	-39
			CO %	-13
			Density: gm/cc	
			1.14	1.12
C/H Ratio			Melting Point: °C	
			-29	
			Freezing Point: °C	
Impact Sensitivity, 2 X₁ Wt:			Boiling Point: °C	
Bureau of Mines Apparatus, cm	<u>100</u>	<u>95/5</u>	101	
Sample Wt 20 mg	100+	100+	Refractive Index, n_D²⁰	
Picatinny Arsenal A, paratus, in.				
Sample Wt, mg	20	20		
Friction Per Calum Test:			Vacuum Stability Test:	
Steel Shoe	Unaffected		cc/40 Hrs, at	
Fiber Shoe	Unaffected		90°C	
Cifle Bullet Impact Test: 10 Trials			100°C	
			120°C	
	%	%	135°C	
Explosions	0	0	150°C	
Partials	0	0	200 Gram Bomb Sand Test:	
Burned	0	0		
Unaffected	100	100	Sand, gm	
			<u>8.1</u>	
			<u>50.6</u>	
Explosion Temperature:			Sensitivity to Initiation:	
Seconds, 0.1	<u>100</u>	<u>95/5</u>	Minimum Detonating Charge, gm	
1			Mercury Fulminate	
5	430	430	Lead Azide	
10			Tetryl	
15			Ballistic Mortar, % TNT:	
20				
75°C International Heat Test:			Trauzl Test, %	
% Loss in 48 Hrs			134	
100°C Heat Test:			Plate Dent Test:	
% Loss, 1st 48 Hrs			Method	
% Loss, 2nd 48 Hrs			Condition	
Explosion in 100 Hrs			Confined	
			Density, gm/cc	
			Brisance, % TNT	
Flammability Index:			Detonation Rate:	
			1/32"*	
			Confinement	
			Glass	
			Condition	
			Liquid	
			Charge Diameter, in.	
			1.25	
			Density, gm/cc	
			1.14	
			Rate, meters/second	
			6210	
			*Tube wall thickness	
			6165	

PLX (Liquid)

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Booster Sensitivity Test:		<u>Nitromethane</u>	Decomposition Equation: (d)	<u>Nitromethane</u>
Condition			Oxygen, atoms/sec (Z/sec)	$10^{14.6}$
Tetryl, gm			Heat, kilocalorie/mole (ΔH , kcal/mol)	56.6
Wax, in. for 50% Detonation			Temperature Range, °C	330-430
Wax, gm			Phase	Gaseous
Density, gm/cc				
Heat of:		(a)	Armor Plate Impact Test:	
Combustion, cal/gm		2830	60 mm Mortar Projectile:	
Explosion, cal/gm			50% Inert, Velocity, ft/sec	
Gas Volume, cc/gm			Aluminum Fineness	
Formation, cal/gm		-348	500-lb General Purpose Bomb:	
Fusion, cal/gm			Plate Thickness, inches	
Vaporization, cal/gm		149	1	
Specific Heat: cal/gm/°C (b)			$1\frac{1}{4}$	
$C_p = 0.4209 - 0.00076t + 0.0000061t^2$			$1\frac{1}{2}$	
			for 15°C to 70°C	
$1\frac{3}{4}$				
Burning Rate:			Bomb Drop Test:	
cm/sec			T7, 20-25-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 Scale:			Low Order	
Young's Modulus:			High Order	
E' , dynes/cm ²			1000-lb General Purpose Bomb vs Concrete:	
E , lb/inch ²			Height, ft	
Density gm/cc			Trials	
Compressive Strength: lb/inch²			Unaffected	
Vapor Pressure:		(c)	Low Order	
°C	mm Mercury		High Order	
70	258			
85	444			

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PLX (Liquid)

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth			
	Glass Cones	Steel Cones									
Hole Volume											
Hole Depth											
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Color: Light yellow Principal Uses: Minefield clearing Method of Loading: Pumping Loading Density: gm/cc <table border="0"> <tr> <td>100</td> <td>95/5</td> </tr> <tr> <td>1.14</td> <td>1.12</td> </tr> </table>	100	95/5	1.14	1.12						
100	95/5										
1.14	1.12										
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Components stored separately; mixed only when ready to use Hazard Class (Quantity-Distance) Compatibility Group Exudation Minimum Propagating Thickness, in: <table border="0"> <tr> <td>100</td> <td>95/5</td> </tr> <tr> <td>0.5</td> <td>0.063</td> </tr> </table> Viscosity, centipoises: (c) <table border="0"> <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> Compatibility with Metals: Stainless steel, mild steel and duriron not affected; corrodes brass.	100	95/5	0.5	0.063	Temp, 10°C	0.748	25°C	0.625	40°C	0.533
100	95/5										
0.5	0.063										
Temp, 10°C	0.748										
25°C	0.625										
40°C	0.533										

FLX (Liquid)

AMCP 706-177

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 443,707 (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. Rowen, PATR No. 1565, 17 September 1945).

References:⁶³

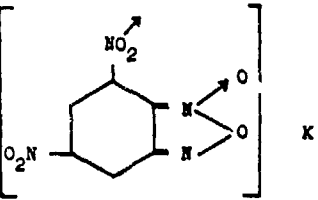
- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," Ind Engr Chem 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).
- (c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).
- (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. Bull, "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>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1660	1681	2113	1565	2016	1747	1708	1619
	1831						

⁶³See footnote 1, page 16.

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Potassium Dinitrobenzofuroxan (KDNBF)

Composition: % C 27.3 H 0.4 N 21.2 O 36.3 K 14.8 C/H Ratio 0.416			
		Molecular Weight: ($KC_6H_4N_4O_6$)	225
		Oxygen Balance:	
		CO ₂ %	-60
		CO %	-18
		Density: gm/cc	2.21
		Melting Point: °C	Explodes 210
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 lb wt) 6 Sample Wt, mg 7		Boiling Point: °C	
		Refractive Index, n_D^{20}	
		n_D^{25}	
		n_D^{30}	
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Explodes		Vacuum Stability Test:	
		cc/40 Hrs, at	
		90°C	
		100°C	
		120°C	
		135°C	
		150°C	
Rifle Bullet Impact Tests: Trials Explosions % Partial Burned Unaffected		200 Gram Bomb Sand Test:	
		Sand, gm	44.8
		Black powder size 9.5	43.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 250 10 15 20		Sensitivity to Initiation:	
		Minimum Detonating Charge, gm	
		Mercury Fulminate	0.30 0.20
		Lead Azide	0.10
		Tetryl	
		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test:	
		Method	
		Condition	
		Confined	
		Density, gm/cc	
		Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		Detonation Rate:	
		Confinement	
		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	
Flammability Index:			
Hygroscopicity: % 30°C, 75% RH 0.11 30°C, 90% RH 0.27			
Volatility:			

Potassium Dinitrobenzofuroxan (KDNBF)

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Booster Sensitivity Tests: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalories/mole (ΔH , kcal/mol) Temperature Range, °C Phase										
Heat of: Combustion, cal/gm 2209 Explosion, cal/gm 725 Gas Volume, cc/gm 604 Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4										
Specific Heat: cal/gm/°C (b) <table> <tr> <th>°C</th><th></th></tr> <tr> <td>-50</td><td>0.217</td></tr> <tr> <td>0</td><td>0.217</td></tr> <tr> <td>25</td><td>0.217</td></tr> <tr> <td>50</td><td>0.217</td></tr> </table>	°C		-50	0.217	0	0.217	25	0.217	50	0.217	
°C											
-50	0.217										
0	0.217										
25	0.217										
50	0.217										
Burning Rate: cm/sec											
Thermal Conductivity: cal/sec/cm/°C											
Coefficient of Expansion: Linear, %/°C Volume, %/°C											
Hardness, Mohs' Scale:											
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	Bomb Drop Test: 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										
Compressive Strength: lb/inch²											
Vapor Pressure: °C mm Mercury											

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Potassium Dinitrobenzofuroxan (KDNEF)

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Orange to brown Principal Use: Primary explosive Method of Loading: Pressed Loading Density: gm/cc psi x 10 ³ 10 20 30 40 80 1.63 1.77 1.81 1.86 1.98 Storage: Method Cut Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group M (wet) Exudation <u>Solubility in Water,</u> <u>gm/100 gm solvent, at:</u> 30°C 0.245 <u>Stab Sensitivity:</u> <table><tr><th>Density</th><th colspan="3">Firing Point (inch-ounces)</th></tr><tr><th>gm/cc</th><th>0%</th><th>50%</th><th>100%</th></tr><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></table> <u>Activation Energy:</u> kcal/mol 82.6 Induction Period, sec 0.5-10	Density	Firing Point (inch-ounces)			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	Firing Point (inch-ounces)																																
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																														
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																																	

Potassium Dinitrobenzfuroxan (KDDBF)

AMCF 706-177

Preparation of Potassium Salt of 4,6-dinitrobenzfuroxan: (a)

Benzfuroxan, made by the reaction of ortho-nitroaniline and alkaline sodium hypochlorite, was dissolved in 6 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-dinitrobenzfuroxan 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-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: ⁶⁴

(a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Contribution to the Chemistry of Benzfuroxan Derivatives," J Am Chem Soc 76, 2233 (1954).

(b) C. Leuchitz, 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 Dinitrobenzfuroxan:

<u>2</u>	<u>3</u>	<u>6</u>	<u>2</u>
2122	2093	2146	2179

⁶⁴See footnote 1, page 10.

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PTX-1

Composition: %		Molecular Weight: 252	
RDX	30	Oxygen Balance: CO ₂ % -45 CO % -9	
Tetryl	50	Density: gm/cc 1.68	
TNT	20	Melting Point: °C Eutectic 67	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 44 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Rifle Bullet Impact Test: Trials Explosions % 20 Partials 20 Burned 0 Unaffected 60		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.0 120°C 135°C 150°C	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		200 Gram Bomb Sand Test: Sand, gm 54.8	
75°C International Heat Test: % Loss in 48 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.22* Tetryl *Alternative initiating charges.	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Ballistic Mortar, % TNT: (a) 132	
Flammability Index:		Treuzl Test, % TNT:	
Hygroscopicity: % 30°C, 90% RH, 15 days 0.00		Plate Dent Test: (b) Method B Condition Cast Confined No Density, gm/cc 1.68 Brisance, % TNT 127	
Volatility:		Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.64 Rate, meters/second 7655	

PTX-1

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.64 Charge Wt, lb 2.180 Total No. of Fragments: For TNT 703 For Subject HE 999 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.63 Charge Wt, lb 0.864 Total No. of Fragments: For TNT 514 For Subject HE 685		Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones Hole Volume Hole Depth </div>	
		Color:	
		Principal Uses: Land mines and demolition charges	
		Method of Loading:	Cast
		Loading Density: gm/cc	1.68
Fragment Velocity: ft/sec At 9 ft 2690 At 25 1/4 ft 2460 Density, gm/cc 1.64		Storage:	
		Method	Dry
		Hazard Class (Quantity-Distance)	Class 9
		Compatibility Group	Group I
		Exudation	Exudes at 65°C
Blast (Relative to TNT): Air: (d) Peak Pressure 111 Impulse 109 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy		Preparation: The ternary explosive system consisting of RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetryl (40/60) 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-1 is also prepared by adding tetryl to RDX Composition B.	
		Compatibility with Metals:	
		Dry: Aluminum, mild steel not affected.	
		Wet: Aluminum, mild steel not affected.	
Booster Sensitivity Test: (c)			
Condition	Pressed	Cast	
Tetryl, gm	100	100	
Wax, in. for 50% Detonation	1.94	1.82	
Density, gm/cc	1.61	1.68	

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PTX-1Origin:

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/tetryl/TNT, designated PTX-1 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-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 exudation.

References:⁶⁵

(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) 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:

<u>0</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>9</u>
1530	1402	1623	1466	1437	1379
			1506		1429
					1469

⁶⁵See footnote 1, page 10.

PTX-2

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Composition: %		Molecular Weight: 244 243	
RDY	44 - 41	Oxygen Balance:	
PETN	28 - 26	CO ₂ %	-33 -36
TNT	28 - 33	CO %	-3 -4
C/H Ratio		Density: gm/cc 1.70	
Impact Sensitivity, 2 Kg Wt: Bureau of Min.s Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Melting Point: °C Eutectic 75	
35		Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Boiling Point: °C	
Crackles		Refractive Index, n_D²⁰	
Rifle Bullet Impact Test: Trials		Vacuum Stability Test:	
Explosions	60	cc/40 Hrs, at	
Partials	0	90°C	
Burned	0	100°C	2.6
Unaffected	40	120°C	11+
Explosion Temperature: °C		135°C	
Seconds, 0.1 (no cap used)		150°C	
1		200 Gress Bomb Sand Test:	
5		Sand, gm	16.9
10		Sensitivity to Initiation:	
15		Minimum Detonating Charge, gm	
20		Mercury Fulminate	0.21
75°C International Heat Test: % Loss in 48 Hrs		Lead Azide	0.00
100°C Heat Test:		Tetryl	0.00
% Loss, 1st 48 Hrs		Ballistic Mortar, % TNT: (a) 138	
% Loss, 2nd 48 Hrs		Trawl Test, % TNT:	
Explosion in 100 Hrs		Plate Dent Test: (b)	
Flammability Index:		Method	B
Hygroscopicity: % 30°C, 90% RH, 15 days 0.00		Condition	Cast
Volatility:		Confined	No
		Density, gm/cc	1.71
		Brisance, % TNT	141
		Detonation Rate:	
		Confinement	None
		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.70
		Rate, meters/second	8065

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PTX-2

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.68 Charge Wt, lb 2.226 Total No. of Fragments: For TNT 703 For Subject HE 1128 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.70 Charge Wt, lb 0.897 Total No. of Fragments: For TNT 514 For Subject HE 750	Shaped Charge Effectiveness, TNT = 160: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume ~130 Hole Depth
Fragment Velocity: ft/sec At 9 ft 3020 At 25 1/2 ft 2850 Density, gm/cc 1.70	Color:
Blast (Relative to TNT): Air: (d) Peak Pressure 113 Impulse 113 Energy -- Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Shaped charges Fragmentation charges
	Method of Loading: Cast
Booster Sensitivity Test: (c) <div style="display: flex; justify-content: space-around;"> Condition Pressed Cast </div> Teteryl, gm 100 100 Max, in. for 50% Detonation 1.87 2.32 Density, gm/cc 1.70 1.61	Loading Density: gm/cc 1.70
	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 65°C
	Preparation: 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. Compatibility with Metals: <u>Dry:</u> Aluminum, mild steel not affected. <u>Wet:</u> Aluminum not affected.

PTX-2

AMCP 706-177

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 Maleite 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:⁶⁶

(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) 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:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>8</u>	<u>9</u>
1530	1482	1483	1414	1445	1466	1838	1379
		1623					1429
							1469

⁶⁶See footnote 1, page 10.

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FVA-4

Composition:		Molecular Weight: 217	
%		Oxygen Balance:	
RDX	90	CO ₂ %	-37
Polyvinyl Acetate	8	CO %	-10
Dibutylphthalate	2	Density: gm/cc Pressed 1.60	
C/H Ratio		Melting Point: °C	
Impact Sensitivity, 2 Kg Wt:		Softening Point: °C 92	
Bureau of Mines Apparatus, cm	39	Freezing Point: °C	
Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.	9	Refractive Index, n_D²⁰	
Sample Wt, mg	13	n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Crackles	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test: 5 Trials *		100°C	0.45
Explosions	%	120°C	0.88
Partials	0	135°C	--
Burned	60	150°C	11+
Unaffected	20	200 Gram Bomb Sand Test:	
*100 trials at -46°C - Unaffected		Sand, gm	58.5
Explosion Temperature: °C		Sensitivity to Initiation:	
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		Ballistic Mortar, % TNT:	
20		Treuzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.10	Confined	
% Loss, 2nd 48 Hrs	0.06	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	
Hygroscopicity: % 30°C, 90% RH 0.20		Confinement	None
Volatility: 55°C, vacuo, 6 hrs 0.03		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.60
		Rate, meters/second	7910

PVA-4

AMCP 706-177

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Demolition charges Method of Loading: Pressed or extruded
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc 1.60 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 71°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Plasticity: -40°C Cracked 25°C 0.3

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PVA-4Preparation:

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DBP). This formulation was developed by Dr. 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 named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/PVA(AYAT)/DBP 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 + DBP 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.

⁶⁷See footnote 1, page 10.

PVN (Polyvinyl Nitrate)

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Composition: % C 27 H 3.4 N 15.6 O 54 C/H Ratio 0.203 $\left(\begin{array}{c} \\ \text{H}_2\text{C}-\text{CH}-\text{ONO}_2 \\ \end{array} \right)_n$	Molecular Weight: $(\text{C}_2\text{H}_3\text{NO}_3)_n$ (89) _n	
	Oxygen Balance: CO ₂ % -45 CO % -9	
	Density: gm/cc	
	Melting Point: °C (Soft Pt) 50 Freezing Point: °C	
	Boiling Point: °C	
Impact Sensitivity, 2 Kg Wt: 14.86%N Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg	Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
	Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected	
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 16 hours 11+ 120°C 16 hours 11+ 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 49.9	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 265 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide Tetryl	
	Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs 1.9 % Loss, 2nd 48 Hrs 2.1 Explosion in 100 Hrs None	Tressel Test, % TNT:	
	Plate Dent Test: Method Condition Confined Density, gm/cc Brizance, % TNT	
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: % 30°C, 90% RH 0.62		
Volatility:		

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PVN (Polyvinyl Nitrate)

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth											
	Glass Cones	Steel Cones																	
Hole Volume																			
Hole Depth																			
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Method of Loading: Loading 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	Color: Principal Uses: Method of Loading: Loading Density: gm/cc Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation 65.5°C KI Test: <table border="0"> <tr> <td>Minutes</td> <td>60+</td> </tr> </table> 134.5°C Heat Test: <table border="0"> <tr> <td></td> <td><u>Minutes</u></td> </tr> <tr> <td>Salmon Pink</td> <td>20</td> </tr> <tr> <td>Red Fumes</td> <td>25</td> </tr> <tr> <td>Explodes</td> <td>300+</td> </tr> </table> 240-Hour Hydrolysis Test: <table border="0"> <tr> <td>% HNO₃</td> <td>5.07</td> </tr> </table> Heat of: <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2960</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>900</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>838</td> </tr> </table>	Minutes	60+		<u>Minutes</u>	Salmon Pink	20	Red Fumes	25	Explodes	300+	% HNO ₃	5.07	Combustion, cal/gm	2960	Explosion, cal/gm	900	Gas Volume, cc/gm	838
Minutes	60+																		
	<u>Minutes</u>																		
Salmon Pink	20																		
Red Fumes	25																		
Explodes	300+																		
% HNO ₃	5.07																		
Combustion, cal/gm	2960																		
Explosion, cal/gm	900																		
Gas Volume, cc/gm	838																		

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).

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RIPE

Composition:		Molecular Weight:	
%		230	
RDX	85	Oxygen Balance:	
Gulf Crown E Oil	15	CO ₂ % -70	
		CO % -35	
C/H Ratio		Density: gm/cc Hand tamped 1.37	
Impact Sensitivity, 2 K₂ Wt:		Melting Point: °C	
Bureau of Mines Apparatus, cm	53	Freezing Point: °C	
Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.	13	Refractive Index, n_D²⁰	
Sample Wt, mg	25	n _D ²⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C --	
Rifle Bullet Impact Test: Trials		100°C 0.34	
Explosions	%	120°C 0.56	
Partial	0	135°C	
Burned	0	150°C	
Unaffected	100	200 Gram Bomb Sand Test:	
Explosion Temperature: °C		Sand, gm 40.1	
Seconds, 0.1 (no cap used)		Sensitivity to Initiation:	
1		Minimum Detonating Charge, gm	
5 Decomposes; no value obtained		Mercury Fulminate	
10		Lead Azide 0.20	
15		Tetryl	
20		Ballistic Mortar, % TNT: (a) 118	
75°C International Heat Test:		Treuzl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: (b)	
100°C Heat Test:		Method B	
% Loss, 1st 48 Hrs	0.03	Condition Hand tamped	
% Loss, 2nd 48 Hrs	0.04	Confined No	
Explosion in 100 Hrs	None	Density, gm/cc 1.37	
Flammability Index:		Brisance, % TNT 85	
Hygroscopicity: % 30°C, 90% RH 0.04		Detonation Rate:	
Volatility:		Confinement None	
		Condition Hand tamped	
		Charge Diameter, in. 1.0	
		Density, gm/cc 1.37	
		Rate, meters/second 7390	

RIPE

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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.36 Charge Wt, lb 1.766 Total No. of Fragments: For TNT 703 For Subject HE 592 3 inch HE, M12A1 Projectile, Lot KC-5: Density, gm/cc 1.42 Charge Wt, lb 0.756 Total No. of Fragments: For TNT 514 For Subject HE 301	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White Principal Uses: Plastic demolition explosive Method of Loading: Hand tamped Loading Density: gm/cc 1.37
Fragment Velocity: ft/sec At 9 ft 2650 At 23½ ft 2370 Density, gm/cc 1.395	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation None at 85°C in 30 hrs None at 95°C in 48 hrs Exudes at 105°C in 48 hrs
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Preparation: RIPE is manufactured by simple mechanical mixing of RDX in oil.	Origin: RIPE, a mechanical mixture of RDX and Gulf Crown E Oil, was developed in the United States during World War II. References: ⁶⁸ (a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests</u> , OSRD Report No. 5746, 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.

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Silver Azide

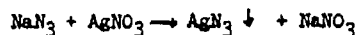
Composition: % N 28.0 Ag 72.0 Ag-N=N=N C/H Ratio	Molecular Weight: (AgN ₃) 150	
	Oxygen Balance: CO ₂ % -5 CO % -5	
	Density: gm/cc Crystal 5.1	
	Melting Point: °C (a) 251 Decomposes rapidly above melting point to silver and nitrogen.	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18	Freezing Point: °C	
	Boiling Point: °C	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: PA Small Apparatus Steel Shoe Detonates Fiber Shoe Detonates	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm (b) 18.9 Black Powder Filler	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cup used) 310 1 -- 5 Explodes 290 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Treuzl Test, % Hg'ONC)₂ (c) 88	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: % (b) 25°C, 100% RH 0.04		
Volatility: 15°C, 24 hrs 0.00		

Silver Azide

AMCP 706-177

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: White to gray Principal Uses: Initiators Method of Loading: Pressed Loading Density: gm/cc Variable																
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-between;"> Method Wet </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-between;"> Compatibility Group Group M </div> <div style="display: flex; justify-content: space-between;"> Exudation None </div>																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Explosive Power: (f) <div style="display: flex; justify-content: space-between;"> Kilogram meters 192,000 </div> <div style="display: flex; justify-content: space-between;"> % Mercury Fulminate 1.097 </div>	Initiating Efficiency: <div style="display: flex; justify-content: space-between;"> Grams Required to Give Complete Initiation of TNT (c) 0.02-0.05 </div> Solubility in 100 gm Solvent at Room Temperature: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Solvent</th> <th style="text-align: left; border-bottom: 1px solid black;">Grams</th> </tr> </thead> <tbody> <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 colspan="2">Unaffected by water and CO₂. (d)</td> </tr> </tbody> </table> Heat of: <div style="display: flex; justify-content: space-between;"> Explosion, cal/gm (c, d) 452 </div> <div style="display: flex; justify-content: space-between;"> Formation, cal/gm (e) 67.8 </div>	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 ₂ . (d)	
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Unaffected by water and CO ₂ . (d)																	

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Silver AzidePreparation:

Prepare the following aqueous solutions:

- a. 5% NaN_3 , sodium azide, 50 cc
- b. 25% 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 hydrazoic acid (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:⁶⁹

- (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. Schiesstoffe, 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).

⁶⁹See footnote 1, page 10.

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- (g) F. Blechts, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.
- (h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).
- (i) F. G. Haverlak, Examination of 120/45 MM HE Shell, Italian (FMAM-464), PATR No. 1515, 10 April 1945.

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Tetracene

Composition: % C 12.8 H 4.3 N 74.4 O 8.5 C/H Ratio 0.068		Molecular Weight: (C ₂ H ₈ N ₁₀ O) 188 Oxygen Balance: CO ₂ % -60 CO % -43 Density: gm/cc At 3000 psi 1.05 Melting Point: °C Explodes 140-160 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.2; (8 oz wt) 8 Sample Wt, mg		Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sund Test: Sand, gm Black powder Fuse 4.0 28.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 160 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.40 Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs 0.5		Ballistic Mortar, % TNT: Troust Test, % TNT: (a) 61	
100°C Heat Test: % Loss, 1st 48 Hrs 23.2 % Loss, 2nd 48 Hrs 3.4 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: % 30°C, 90% RH 0.77			
Volatility:			

Tetracene

AMCP 706-177

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> <div>Glass Cones</div> <div>Steel Cones</div> </div> Hole Volume Hole Depth Color: Pale yellow Principal Uses: Priming compositions and detonators Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 3000 psi 1.05 Storage: <div> <div>Matted</div> <div>Wet</div> </div>
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Hazard Class (Quantity-Distance): Class 9 Compatibility Group: Group M Exudation: Solubility: Practically insoluble in water, alcohol, acetone, ether, benzene, carbontetrachloride or ethylenedichloride. Sensitivity to Electrostatic Discharge, Joules: (b) <div> <div>Unconfined</div> <div>0.010</div> </div> <div> <div>Confined</div> <div>0.012</div> </div> Heat of: <div> <div>Explosion, cal/gm</div> <div>658</div> </div> <div> <div>Gas Volume, cc/gm</div> <div>1190</div> </div> Initiating Efficiency: Tetracene is not efficient in initiating high explosives.

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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 380, 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:⁷⁰

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

L. C. Smith and E. G. Ryser, 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.

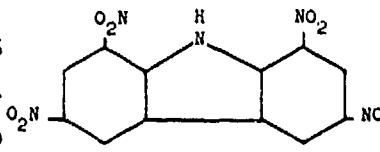
(c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

<u>0</u>	<u>1</u>	<u>2</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1450	11	453	1104 2164	407	318	859 2179

⁷⁰See footnote 1, page 10.

Tetranitrocarbazole (TNC)

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Composition: % C 41.6 H 1.4 N 20.0 O 37.0 C/H Ratio 1.032		Molecular Weight: (C ₁₂ H ₂ N ₂ O ₈) 347	
		Oxygen Balance: CO ₂ % -85 CO % -30	
		Density: gm/cc	
		Melting Point: °C Pure 1,3,6,8-isomer 296	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 14		Boiling Point: °C	
		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.2 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 41.3	
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 Decomposes 470 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.25	
		Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Treuzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Hygroscopicity: % 30°C, 90% RH 0.01			
Volatility:			

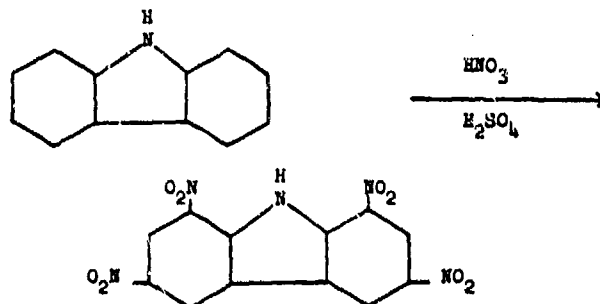
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Tetranitrocarbazole (TNC)

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, (A42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light yellow Principal Uses: Component of igniter and pyrotechnic compositions Method of Loading: Pressed Loading Density: gm/cc																
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group Exudation																
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility in Water, <u>gm/100 gm (%), at:</u> <div style="display: flex; justify-content: space-around;"> 95°C 0.10 </div> <u>Qualitative Solubilities:</u> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;"><u>Solvent</u></th><th style="text-align: left;"><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
<u>Solvent</u>	<u>Solubility</u>																
Nitrobenzene	Very soluble																
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Carbontetrachloride	Insoluble																
Ether	Insoluble																
Ether, petroleum	Insoluble																

Tetranitrocarbazole (TNC)

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Preparation:

Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of H_2SO_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 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. Escalas (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 464,538). The Casella process of

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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:⁷¹

(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.

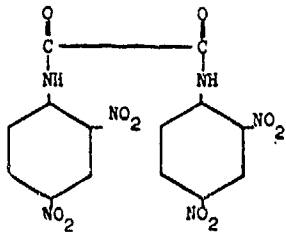
(e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>I</u>
2180	1802	1973	1984	1647 1937

⁷¹See footnote 1, page 10.

2,4,2',4'-Tetranitro-oxanilide (TNO)

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Composition: % C 40.0 H 1.9 N 20.0 O 38.1 C/H Ratio 0.735				Molecular Weight: (C ₁₄ H ₈ N ₆ O ₁₀) 420	
		Oxygen Balance: CO ₂ % -84 CO % -31			
		Density: gm/cc			
		Melting Point: °C Decomposes 313			
		Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 30 Sample Wt, mg 11		Boiling Point: °C			
		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁰			
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C -- 100°C -- 120°C 0.11 135°C 150°C			
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 16.3			
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 392 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25			
		Ballistic Mortar, % TNT:			
		Treuzl Test, % TNT:			
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT			
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second			
Flammability Index:					
Hygroscopicity: % 30°C, 90% RH Trace					
Volatility:					

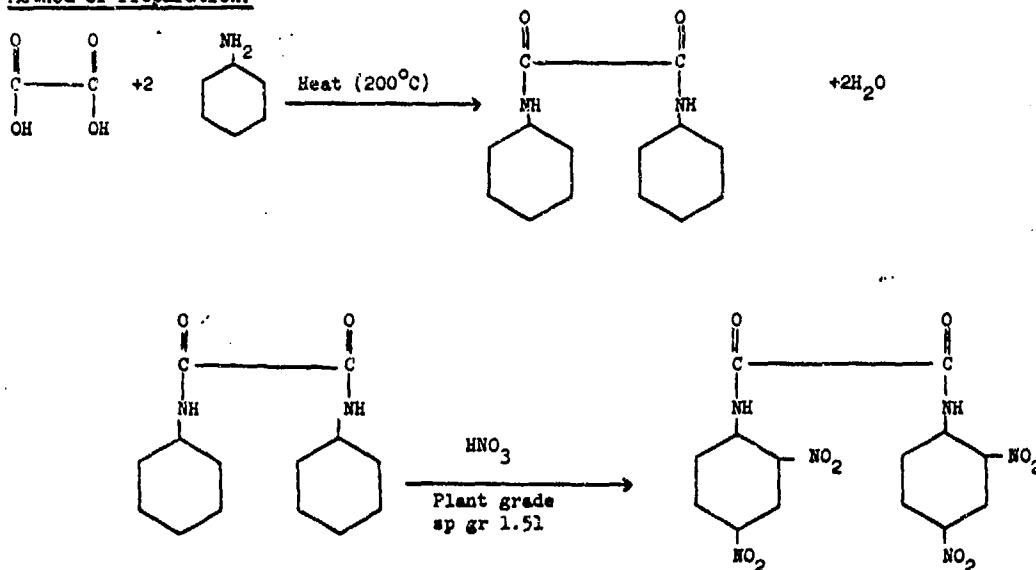
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2,4,2',4'-Tetranitro-oxanilide (TNO)

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light yellow Principal Uses: Component of black powder type or pyrotechnic compositions Method of Loading: Pressed and extruded compositions Loading Density: gm/cc																				
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: <div style="display: flex; justify-content: space-between;"> Method Dry </div> <div style="display: flex; justify-content: space-between;"> Hazard Class (Quantity-Distance) Class 9 </div> Compatibility Group Exudation																				
Blow (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility, gm/100 cc Solvent, in: <div style="display: flex; justify-content: space-between;"> <div> Water Nitrobenzene </div> <div style="text-align: center;"> <div style="display: flex; align-items: center;"> <div style="border-bottom: 1px solid black; padding: 0 5px;">°C</div> <div style="border-bottom: 1px solid black; padding: 0 5px;">g</div> </div> 100 <0.10 150 >15 </div> </div> Qualitative Solubilities: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Solvent</th><th style="text-align: left; border-bottom: 1px solid black;">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>	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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Nitric acid	Soluble																				
Caustic potash	Soluble																				
Dimethyl formamide	Very soluble																				

2,4,2',4'-Tetranitro-oxanilide (TNO)

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Method of Preparation:Oxanilide:

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 Büchner 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:⁷²

- (a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-38, 20 December 1954.

⁷²See footnote 1, page 10.

Tetryl

AMCP 706-177

Composition: % C 29.3 H 1.7 N 24.4 O 44.6 C/H Ratio 0.420		Molecular Weight: (C ₇ H ₅ N ₅ O ₈) 287 Oxygen Balance: CO ₂ % -47 CO % -8 Density: gm/cc Crystal 1.73 Melting Point: °C 130 Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 26 Sample Wt 20 mg Picc'inny Arsenal Apparatus, in. 8 Sample Wt, mg 18		Boiling Point: °C Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Friction Pendulum Test: Steel Shoe Crackles Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C -- 100°C 0.3 120°C 1.0 135°C -- 150°C 11+	
Rifle Bullet Impact Test: Trials Explosions % 13 Partial 54 Burned 10 Unaffected 23		200 Gram Bomb Sand Test: Sand, gm 54.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 340 1 314 5 Ignites 257 10 238 15 236 20 234		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.20* Lead Azide 0.10* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs 0.01		Ballistic Mortar, % TNT: (a) 130 Trawl Test, % TNT: (b) 125	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None		Plate Dens Test: (c) Method A B Condition Pressed Pressed Confined Yes No Density, gm/cc 1.50 1.59 1.36 Brisance, % TNT 116 115 96	
Flammability Index: 244		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.71 Rate, meters/second 7850	
Hygroscopicity: % 30°C, 90% RH 0.04			
Volatility: 25°C 0.00			

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Tetryl

Booster Sensitivity Test: Condition (d) Tetryl, gm Pressed Wax, in. for 50% Detonation 100 Wax, gm 2.01 Density, gm/cc 1.58	Decomposition Equation: Oxygen, atoms/sec (g) 10 ¹⁵ 4 (h) 10 ¹² 9 Heat, kilocalorie/mole (Z/sec) 38.4 34.9 (ΔH, kcal/mol) Temperature Range, °C 211-260 132-164 Phase Liquid Liquid
Heat of: Combustion, cal/gm 2925 Explosion, cal/gm 1080-1130 Gas Volume, cc/gm 760 Formation, cal/gm -14 Fusion, cal/gm (e) 22.2 Temperature, °C 127	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C (e) -100 0.182 - 50 0.200 0 0.212 50 0.223 100 0.236	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: (f) cal/sec/cm/°C 5.81 x 10 ⁻⁴ at 1.394 gm/cc 6.83 x 10 ⁻⁴ at 1.528 gm/cc	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: °C mm Mercury	

Tetryl

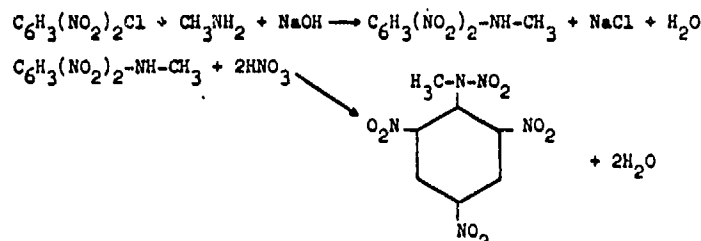
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Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.58 Charge Wt, lb 2.052 Total No. of Fragments: For TNT 703 For Subject HE 864 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.62 Charge Wt, lb 0.848 Total No. of Fragments: For TNT 514 For Subject HE 605	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Light yellow Principal Uses: Boosters; ingredient of explosive mixtures, detonators, and blasting caps Method of Loading: Pressed Loading Density: gm/cc See below
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 1 Compatibility Group Group 1 Exudation Does not exude at 65°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Loading Density: gm/cc Cast 1.62 Pressed psi x 10 ³ 0 3 5 10 12 15 20 0.9 1.40 1.47 1.57 1.60 1.63 1.67 30 1.71 Effect of Temperature on Rate of Detonation: (°) 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 dinitrochlorobenzene 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 80/1.8/18.2 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.

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TetrylSensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (1)

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
80	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	82
30	4.4	100	149
40	5.4	120	545
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.

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TetrylDestruction 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:⁷³

(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---Sprengstoffv, 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. Gamov, Theory of the Detonation Process, NAVORD Report No. 10-4C, 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. I. 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
600	361	582	493	144	195	556	197	438	179
770	381	832	623	294	425	786	637	628	319
810	621	982	833	314	525	986	707	708	609
1140	861	1192	863	634	565	1086	807	788	709
1200	1041	1352	1113	774	625	1126	837	838	849
1350	1131	1372	1373	784	635	1316	857	1418	999
1375	1261	1402	2053	874	845	1376	1047	1788	1029
1400	1311	1452	2163	904	925	1416	1137	1828	1209
1450	1431	1592	2233	1134	1145	1446	1287	1838	1379
1500	1471			1164	1285	1466	1337		1429
1510	1611			1234	1405	1556	1367		1489
1600	1651			1264	1585	1636	1437		1819
				2024	1885	1956	1737		1969
				2204	1935		1797		
					2105		1937		
					2125				
					2205				

⁷³See footnote 1, page 10.

Tetrytol, 80/20

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Composition: %		Molecular Weight: 274	
Tetryl	80	Oxygen Balance: CO ₂ % -52 CO % -11	
TNT	20	Density: gm/cc Cast 1.51	
C/H Ratio		Melting Point: °C 68	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 17		Boiling Point: °C	
		Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.0 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test:	Trials	200 Gram Bomb Sand Test: Sand, gm 54.0	
Explosions	% 0		
Partials	20		
Burned	0		
Unaffected	80		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 290 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.22* Lead Azide 0.17* Tetryl *Alternative initiating charges.	
		Ballistic Meter, % TNT:	
		Troust Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.5 Explosion in 100 Hrs None			
Flammability Index: Will not continue to burn			
Hygroscopicity: % 0.02		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Velocity:			

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Tetrytol, 80/20

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
Fragment Velocity: ft/sec At 11 ft At 25 1/2 ft Density, gm/cc	Color: Light yellow to buff									
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: Burstern, demolition blocks									
	Method of Loading:									
	Loading Density: gm/cc									
	Storage: <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>Exudes at 65°C</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	Exudes at 65°C	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation	Exudes at 65°C									

Tetrytol, 75/25

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Composition: %		Molecular Weight: 270	
Tetryl 75		Oxygen Balance:	
TNT 25		CO ₂ % -54	
		CO % -12	
C/H Ratio		Density: gm/cc Cast 1.59	
		Melting Point: °C 68	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm 28		Refractive Index, n_D²⁰	
Sample Wt 20 mg 10		n _D ²⁵	
Picatinny Arsenal Apparatus, in. 17		n _D ³⁰	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe Cracks		cc/40 Hrs, at	
Fiber Shoe Unaffected		90°C	
Rifle Bullet Impact Test: Trials		100°C 3.2	
Explosions % 0		120°C 11+	
Portals 30		135°C	
Burned 0		150°C	
Unaffected 70		200 Gram Bomb Sand Test:	
Explosion Temperature: °C		Sand, gm 53.7	
Seconds, 0.1 (no cap used)		Sensitivity to Initiation:	
1		Minimum Detonating Charge, gm	
5 Ignites 310		Mercury Fulminate 0.23*	
10		Lead Azide 0.19*	
15		*Alternative initiating charges.	
20		Ballistic Master, % TNT: (a) 122	
75°C International Heat Test:		Tensile Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test: (b)	
100°C Heat Test:		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	
Flammability Index: Will not continue to burn		Brinell, % TNT 118 114	
Hygroscopicity: % 0.03		Detonation Rate:	
Va Jolley:		Confinement None	
		Condition Cast	
		Charge Diameter, in. 1.0	
		Density, gm/cc 1.60	
		Rate, meters/second 7385	

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Tetryl, 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	1.59		
Charge Wt, lb	2.101		
Total No. of Fragments:			
For TNT	703		
For Subject HE	857		
3 inch HE, M42A1 Projectile, Lot KC-5:			
Density, gm/cc	1.60		
Charge Wt, lb	0.845		
Total No. of Fragments:			
For TNT	514		
For Subject HE	591		
Fragment Velocity: ft/sec			
At 9 ft			
At 15½ 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			
	Method of Loading: Cast		
	Loading Density: gm/cc 1.59		
	Storage:		
	Method Dry		
	Hazard Class (Quantity-Distance) Class 9		
	Compatibility Group Group I		
	Exudation Exudes at 65°C		
	Eutectic Temperature, °C: 67.5		
	gm Tetryl/100 gm TNT		
	67.5°C 54-82		
	Booster Sensitivity Test: (c)		
	Condition Cast		
	Tetryl, gm 100		
	Wax, in. for 50% Detonation 1.66		
	Density, gm/cc 1.66		

Tetrytol, 70/30

AMCP 706-177

Composition: %		Molecular Weight: 266	
Tetryl	70	Oxygen Balance: CO ₂ % -55 CO % -13	
TNT	30	Density: gm/cc	Cast 1.60
C/H Ratio		Melting Point: °C 68	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 18		Boiling Point: °C	
		Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 3.2 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partials 55 Burned 0 Unaffected 45		200 Gram Bomb Sand Test: Sand, gm 53.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 416 1 387 5 Ignites 320 10 302 15 289 20 275		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.22* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs:		Ballistic Marker, % TNT: (a) 120	
100°C Heat Test: % Loss, 1st 48 Hrs 0.1 % Loss, 2nd 48 Hrs 0.1 Explosion in 100 Hrs None		Tressel Test, % TNT: Plate Dent Test: (b) Method B Condition Cast Confined Yes Density, gm/cc 1.60 Brisance, % TNT 117	
Flammability Index: Will not continue to burn		Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7340	
Hygroscopicity: % 0.02			
Volatility:			

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Tetrytol, 70/30

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.60 Charge Wt, lb 2.090 Total No. of Fragments: For TNT 703 For Subject HE 840 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.60 Charge Wt, lb 0.842 Total No. of Fragments: For TNT 514 For Subject HE 585	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Light yellow to buff Principal Uses: Bursting, demolition blocks Method of Loading: Cast Loading Density: gm/cc 1.60
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	

Tetrytol, 65/35

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Composition: % Tetryl 65 TNT 35 C/H Ratio	Molecular Weight: 264	
	Oxygen Balance: CO ₂ % -56 CO % -14	
	Density: gm/cc 1.60	
	Melting Point: °C 68	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Friction Pendulum Test: Steel Shoe Cracks Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.8 120°C 11+ 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partials 10 Burned 0 Unaffected 90	200 Gram Bomb Sand Test: Sand, gm 52.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 325 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.23* Tetryl *Alternative initiating charges.	
75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % TNT:	
Flammability Index: Will not continue to burn	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 0.02	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7310	
Volatility:		

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Tetrytol, 65/35

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.61 Charge Wt, lb 2.010 Total No. of Fragments: For TNT 703 For Subject HE 856 3 inch HE, M42A1 Projectile, Lot KC-5: Density, gm/cc 1.60 Charge Wt, lb 0.845 Total No. of Fragments: For TNT 514 For Subject HE 585	Shaped Charge Effectiveness, TNT = 100: <table><tr><td></td><td>(d)</td><td>(e)</td></tr><tr><td></td><td>Glass Cones</td><td>Steel Cones</td></tr><tr><td>Hole Volume</td><td>133</td><td>126</td></tr><tr><td>Hole Depth</td><td>120</td><td>119</td></tr></table> Color: Light yellow to buff Principal Uses: Burstera, demolition blocks Method of Loading: Cast Loading Density: gm/cc 1.60		(d)	(e)		Glass Cones	Steel Cones	Hole Volume	133	126	Hole Depth	120	119
	(d)	(e)											
	Glass Cones	Steel Cones											
Hole Volume	133	126											
Hole Depth	120	119											
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation Exudes at 65°C												
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy													

Tetrytol, 80/20, 75/25, 70/30, 65/35

AMCP 706-177

Compatibility 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:⁷⁴

(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) 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.

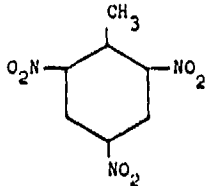
(f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
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							

⁷⁴See footnote 1, page 10.

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TNT (Trinitrotoluene)

Composition: % C 37.0 H 2.2 N 18.5 O 42.3 C/H Ratio 0.549				Molecular Weight: (C ₇ H ₅ N ₃ O ₆) 227	
		Oxygen Balance: CO ₂ % -74 CO % -25		Density: gm/cc Crystal 1.65	
				Melting Point: °C 81	
				Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 95-100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14-15 Sample Wt, mg 17				Boiling Point: °C	
				Refractive Index, n_D α 1.5430 β 1.6742 γ 1.717	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected				Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.10 120°C 0.23 135°C 0.44 150°C 0.65	
Rifle Bullet Impact Test: Trials Explosions % 4 Partial 0 Burned 0 Unaffected 6				200 Gram Bomb Sand Test: Sand, gm 48.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 570 1 520 5 Decomposes 475 10 465 15 20				Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.24* Lead Azide 0.27* Tetryl *Alternative initiating charges.	
				Ballistic Mortar, % TNT: Std=100	
				Trauzl Test, % TNT: Std=100	
75°C International Heat Test: % Loss in 48 Hrs 0.04				Plate Dent Test: (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	
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.2 Explosion in 100 Hrs None				Detonation Rate: 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	
Flexibility Index: (b) 100					
Hygroscopicity: % 30°C, 90% RH 0.03					
Volatility: 30°C N11					

TNT (Trinitrotoluene)

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Booster Sensitivity Test: (c) Condition Pressed Cast Tetryl, gm 100 100 Wax, in. for 50% Detonation 1.68 0.82 Wax, gm Density, gm/cc 1.55 1.60			Decomposition Equation: (h) (i) Oxygen, atoms/sec $10^{11.4}$ $10^{12.2}$ (Z/sec) Heat, kilocalorie/mole 34.4 43.4 (ΔH , kcal/mol) Temperature Range, °C 275-310 238-277 Phase Liquid Liquid		
Heat of: (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			Armor Plate Impact Test: 60 mm Mortar Projectile: (j) 50% Inert, Velocity, ft/sec >1100 Aluminum Fineness 500-lb General Purpose Bombs: (j)		
Specific Heat: cal/gm/°C °C 0 0.309 20 0.328 50 0.353 80 0.374			Plate Thickness, inches <u>Trials</u> <u>% Inert</u> 1 0 1 1/4 0 1 1/2 4 100 1 3/4 4 50		
Burning Rate: cm/sec			Bomb Drop Test: T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 5000-6000		
Thermal Conductivity: cal/sec/cm/°C See next page.			500-lb General Purpose Bomb vs Concrete: <u>No Seal</u> <u>Seal</u> Height, ft 4,000 4-5,000 Trials 26 20 Unaffected 24 20 Low Order 2 0 High Order 0 0		
Coefficient of Expansion: (b) Linear, %/°C -40°C to 60°C 5.4×10^{-5} (b) -40°C to 60°C 6.7×10^{-5} Volume, %/°C 27°C to 80°C 16×10^{-5} (b) 16°C to 70°C 26.3×10^{-5} (n)			1000-lb General Purpose Bomb vs Concrete: <u>No Seal</u> <u>Seal</u> Height, ft 5,000 5,000 Trials 21 26 Unaffected 18 22 Low Order 0 0 High Order 3 4		
Hardness, Mohs' Scale: (e) 1.4					
Young's Modulus: (b) E', dynes/cm ² 5.45×10^{10} E, lb/inch ² 0.79×10^6 Density, gm/cc 161					
Compressive Strength: lb/inch ² 13800-14000 Density, gm/cc 1.62					
Vapor Pressure: (f) °C mm Mercury 80 0.042 85 0.053 90 0.067 95 0.085 100 0.106					

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TNT (Trinitrotoluene)

Fragmentation Test:		Shaped Charge Effectiveness, TNT = 100:	
90 mm HE, M71 Projectile, Lot WC-91:		Glass Cones	Steel Cones
Density, gm/cc	1.60	Hole Volume	100
Charge Wt, lb	2.104	Hole Depth	100
Total No. of Fragments:		Color:	Light yellow
For TNT	703	Principal Uses: GP bombs, HE projectiles, demolition charges, depth charges, grenades, propellant compositions	
For Subject HE	703		
3 inch HE, M42A1 Projectile, Lot KC-5:		Method of Loading: 1. Cast 2. Pressed	
Density, gm/cc	1.60	Loading Density: gm/cc See below	
Charge Wt, lb	0.848		
Total No. of Fragments:		Storage:	
For TNT	514		
For Subject HE	514	Method Dry	
Fragment Velocity: ft/sec (k)		Hazard Class (Quantity-Distance) Class 9	
At 9 ft	2600	Compatibility Group Group I	
At 25 ft	2360	Exudation None at 65°C	
Density, gm/cc	1.58	Loading Density: gm/cc	
Blast (Relative to TNT):		1. Cast 1.58-1.59 2. Pressed psi x 10 ³	
Air:		3 5 10 15 20 30 50	
Peak Pressure	100	1.35 1.40 1.45 1.52 1.55 1.59 1.6	
Impulse	100	Thermal Conductivity:	
Energy	100	cal/sec/cm/°C	
Air, Confined:		Density 1.19 gm/cc (g) 5.28 x 10 ⁻⁴	
Impulse	100	1.51 gm/cc (g) 7.12 x 10 ⁻⁴	
Under Water:		1.54 gm/cc (b) 5.6 x 10 ⁻⁴	
Peak Pressure	100	1.67 gm/cc (g) 12.21 x 10 ⁻⁴	
Impulse	100	Viscosity, poises:	
Energy	100	Temp, 85°C 0.139	
Underground:		100°C 0.095	
Peak Pressure	100	Bulk Modulus at Room Temperature (25°-30°C): (m)	
Impulse	100	Dynes/cm ² x 10 ⁻¹⁰ 2.92	
Energy	100	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	0.05
Confined	4.4

Impact Sensitivity versus Temperature:

Picatinny Arsenal Apparatus, 2 kg wt, inches:

°C	inches
-40	17
Room	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:

<u>Standard Iron Bomb:</u>	<u>Room Temperature</u>	<u>105° to 110°C</u>
No Air Space		
Trials	10	10
Explosions	1 very low order	7
Air Space		
Trials	10	10
Explosions	0	0
<u>Tin or Cardboard Bombs:</u>		
With or Without Air Space		
Trials	10	10
Explosions	0	0

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TNT (Trinitrotoluene)

Explosion Temperature versus TNT Initial Temperature:

<u>TNT Temperature, Initial</u>	<u>Explosion Temperature, °C</u>
Room	470 (Decomposes)
105°-100°C	480 (Decomposes)

Explosion Temperature versus Confinement, °C:

Unconfined	Decomposes	470
Sealed in glass capillary	Explodes	320-335

Viscosity at 80.5°C:

Viscosity, X, cp $\log X = 0.046 S + 1.25$
 S = % solid in slurry
 Particle size effect, small

Density, gm/cc:

<u>°C</u>	<u>State</u>	<u>gm/cc</u>
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)

<u>Water</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	0.0100	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

<u>Carbon tetrachloride</u>		<u>Ether</u>		<u>Chloroform</u>		<u>Trichloroethylene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.20	0	1.73	0	6	25	3.5
0	0.65	20	3.29	20	19	55	60
40	1.75			40	66		
60	6.90			60	302		
70	17.34						
75	24.35						

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TNT (Trinitrotoluene)

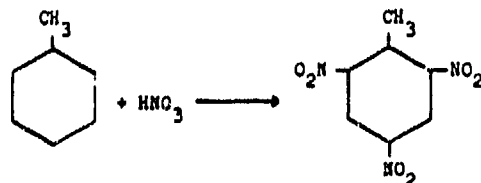
<u>Pyridine</u>		<u>Methyl acetate</u>		<u>Ethylene dichloride</u>		<u>β-Ethoxy-ethyl-acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	140	20	73	20	34	20	29.5
40	250	40	135	40	123	40	49
60	640	50	280	60	460	50	96
70	1250						

<u>Tetrachloro-ethane</u>		<u>Aniline</u>		<u>Isopropyl alcohol</u>		<u>Ethanol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	18	10	6.1	20	0.76	0	0.62
40	50	30	11.5	40	1.96	20	1.25
50	100	50	29	50	2.95	40	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>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.20	0	0.14	20	45
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 counter current, MNT was nitrated to TNT.

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TNT (Trinitrotoluene)

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 nitroxy ion (NO_2^+), on the one hand, and the role of the bisulfate ion (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 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at 30°-40°C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at 30°-40°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°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° and 100°C. Acid addition requires 1 hour, and stirring at 90°-100°C is continued 2 more hours.

While the dinitration mixture is still at 90°C, 145 gm fuming sulfuric acid (oleum containing 15% free 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°-115°C over 1½-2 hours. The mixture is stirred at 100°-115°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°-95°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°C for ½ 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 Hoesermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 100; 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:⁷⁵

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

⁷⁵See 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 Tetryl 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-2861, 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, NIDRC, Report on HBX 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. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
- (m) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1956.
- (n) Mantrov, 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	288	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	700
1120	1041	1192	743	1224	975	1146	817	1098	739
1140	1121	1272	853	1284	1145	1276	831	1128	779
1170	1311	1292	863	1294	1155	1376	1107	1148	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	1411	1315	1556	1307	1228	1039
1460	1651	1452	1243	1444	1395	1636	1417	1238	1109
1500	1821	1472	1323	1454	1425	1756	1427	1308	1129

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<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	2216	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

Torpex

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Composition:		Molecular Weight:	
%		97	
RDX	42	Oxygen Balance:	
TNT	40	CO ₂ %	
Aluminum	18	CO %	
C/H Ratio		Density: gm/cc	
		Cast	
		1.76-1.81	
		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	42	Refractive Index, n_D²⁰	
Sample Wt 20 mg		n _D ²⁰	
Picatinny Arsenal Apparatus, in.	9	n _D ²⁰	
Sample Wt, mg	15		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test:		100°C	
	Trials	120°C	
	%	135°C	
Explosions	20	150°C	
Partials	80	1.0	
Burned	0		
Unaffected	0	200 Gram Bomb Sand Test:	
Explosion Temperature: °C		Sand, gm	
Seconds, 0.1 (no cap used)		59.5	
1		Sensitivity to Initiation:	
5 Decomposes	260	Minimum Detonating Charge, gm	
10		Mercury Fulminate	
15		Lead Azide	
20		Tetryl	
75°C International Heat Test:		Ballistic Mortar, % TNT: (a)	
% Loss in 48 Hrs		138	
100°C Heat Test:		Troust Test, % TNT: (b)	
% Loss, 1st 48 Hrs		164	
% Loss, 2nd 48 Hrs		Plate Dent Test: (c)	
Explosion in 100 Hrs		Method	
		Condition	
		Confined	
		Density, gm/cc	
		Brisance, % TNT	
Flammability Index:		B	
		Cast	
		No	
		1.83	
		120	
Hygroscopicity: % 30°C, 90% RH		Detonation Rate: (d)	
0.00		Confinement	
		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	
		None	
		Cast	
		1.0	
		1.81	
		7495	
Volatility:			

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Torpex

Booster Sensitivity Test: (c) Condition Pressed Cast Tetryl, gm 10 5 Wax, in. for 50% Detonation Wax, gm 2 0 Density, gm/cc 1.64 1.81			Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase		
Heat of: (a) Combustion, cal/gm 3740 Explosion, cal/gm 1800 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm			Armor Plate Impact Test: 60 mm Mortar Projectile: (a) 50% Inert, Velocity, ft/sec 185 Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1¼ 1½ 1¾		
Specific Heat: cal/gm/°C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24			Bomb Drop Test: 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		
Burning Rate: cm/sec					
Thermal Conductivity: (b) cal/sec/cm/°C 9.7×10^{-4} Density, gm/cc 1.82					
Coefficient of Expansion: Linear, %/°C -73 to 75°C 4.7×10^{-5} (b) Volume, %/°C					
Hardness, Mohr's Scale:					
Young's Modulus: (b) E', dynes/cm ² 9.53×10^{10} E, lb/inch ² 1.38×10^6 Density, gm/cc 1.77					
Compressive Strength: lb/inch ² (b) 2100-2300 Density, gm/cc 1.77					
Vapor Pressure: °C mm Mercury					

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Fragmentation Test:	Shaped Charge Effectiveness, TNT = 100: 50/36.5/13.5	
90 mm HE, M21 Projectile, Lot WC-91:	Glass Cones	Steel Cones
Density, gm/cc	Hole Volume 150	145
Charge Wt, lb	Hole Depth 127	131
Total No. of Fragments:	Color:	Gray
For TNT	703	
For Subject HE	891	
3 inch HE, M42A1 Projectile, Lot KC-5:	Principal Uses:	Depth charges, bombs
Density, gm/cc	1.79	
Charge Wt, lb	0.940	
Total No. of Fragments:	Method of Loading:	Cast
For TNT	514	
For Subject HE	647	
Fragment Velocity: ft/sec	Loading Density: gm/cc	1.76-1.81
At 9 ft	2960	
At 25½ ft	2800	
Density gm/cc	--	
Blast (Relative to TNT):	(e)	
Air:		
Peak Pressure	122	
Impulse	125	
Energy	146	
Air, Confined:		
Impulse	116	
Under Water:		
Peak Pressure	116	
Impulse	127	
Energy	153	
Underground:		
Peak Pressure		
Impulse		
Energy		
	Effect of Temperature on Impact Sensitivity.	
	Temp. °C	PA Impact Test 2 Kg Wt, inches
	25	15
	32	7
	104	8
	Viscosity, poises:	
	Temp, 83°C	4.5
	95°C	2.3

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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</u> <u>unwaxed</u>	<u>Torpex 2</u> <u>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:⁷⁶

(a) Committee of Div 2 and 8, NDRC, Report on HEX 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.

⁷⁶See 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) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.

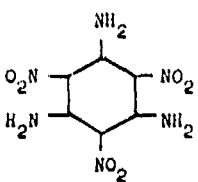
(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1530	1651	1292	2353	1585	1796	1797	1838
				1635			
				1885			
				2355			

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1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)

Composition: % C 27.9 H 2.3 N 32.6 O 37.2 C/H Ratio 0.302		Molecular Weight: ($C_6H_3N_6O_6$) 258 Oxygen Balance: CO ₂ % -56 CO % -19 Density: gm/cc Crystal 1.93 Melting Point: °C 330 (b, c) 360 (a) Freezing Point: °C	
		Boiling Point: °C Refractive Index, n_D^{20} n_D^{25} n_D^{30}	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 7		Friction Pendulum Test: Steel Shoe Fiber Shoe Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C (a, b) 0.36 120°C ---- 135°C ---- 150°C ---- 200 Gram Bomb Sand Test: Sand, gm 42.9	
75°C International Heat Test: % Loss in 48 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ---- Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		Trauzl Test, % TNT: Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.80 Rate, meters/second 7500	
Hygroscopicity: %			
Volatility:			

1,3,5-Triamino-2,4,6-Trinitrobenzene (TATNB)

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25 1/2 ft Density, gm/cc	Color: Yellow
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses:
	Method of Loading: Pressed
	Loading Density: gm/cc At 50,000 psi 1.80
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation
	Detonation Velocity: (a, b, c) <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <u>Density, gm/cc</u> 1.290 1.345 1.675 1.675 1.882 1.835 </div> <div style="text-align: center;"> <u>Meters/sec</u> 5380 5628 6550 6575 7035 7220 </div> </div>
	Heat of: 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 12.5 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 f) 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 f): 1,3,5-trichlorobenzene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobenzene in 65% 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 1882 by C. L. Jackson and J. F. 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. Flurscheim and E. L. Holmes prepared TATNB from benzene free pentanitroaniline by gradually adding it to 10% aqueous ammonia (J Chem Soc, Pt 2, 3045 (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 hexa-aminobenzene. Either decomposition occurred or a hydrochloride of penta-aminobenzene was formed. Flurscheim and Holmes succeeded in reducing TATNB with phenylhydrazine by heating them together up to 200°C (J Chem Soc, Pt 1, 334 (1929)) (Beil 13, 301 and EII, 147).

References:⁷⁷

- (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.

⁷⁷See footnote 1, page 10.

Triethylene Glycol Dinitrate (TEGN) Liquid

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Composition: % C 29.9 H 5.4 N 11.7 O 53.0 C/H Ratio 0.177		$ \begin{array}{c} \text{CH}_2\text{ONO}_2 \\ \\ \text{H}_2\text{C} - \text{O} \\ \\ \text{H}_2\text{C} - \text{O} \\ \\ \text{H}_2\text{C} - \text{O} \\ \\ \text{H}_2\text{C} - \text{O} \\ \\ \text{CH}_2\text{ONO}_2 \end{array} $		Molecular Weight: ($\text{C}_6\text{H}_{12}\text{N}_2\text{O}_8$) 240	
		Oxygen Balance: CO ₂ % -89 CO % -27		Density: gm/cc 20°C 1.33 25°C 1.32	
		Melting Point: °C		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 43 Sample Wt, mg		Boiling Point: °C		Refractive Index, n_D^{20} 1.4540 n_D^{25} n_D^{30}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.45 120°C 8 hours 0.8 135°C 150°C		200 Gram Bomb Sand Test: Sand, gm 14.7	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected		Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 323 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:		Trauzl Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 1.8 % Loss, 2nd 48 Hrs 1.6 Explosion in 100 Hrs None		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		Deterioration Rate: Confinement Dry steel Condition Liquid Charge Diameter, in. 1.25 Density, gm/cc 1.33 Rate, meters/second Fails	
Flammability Index:		Volatility: 60°C, mg/cm ² /hr 40			
Hygroscopicity: %					

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Triethylene Glycol Dinitrate (TEGN) Liquid

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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div> Glass Cones Steel Cones </div> Hole Volume Hole Depth Colors: Principal Uses: Ingredient of rocket and double base propellants Method of Loading: Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm./cc	Storage: Method Liquid Hazard Class (Quantity-Distance) Compatibility Group Exudation
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Solubility in Water, <u>gm/100 gm, at:</u> 25°C 0.55 60°C 0.68 Solubility, gm/100 gm, <u>at 25°C, in:</u> Ether " Alcohol " 2:1 Ether:Alcohol " Acetone " Viscosity, centipoises: Temp, 20°C 13.2 Hydrolysis, % Acid: 10 days at 22°C 0.032 5 days at 60°C 0.029
Heat of: Combustion, cal/gm 3428 Explosion, cal/gm 357 Gas Volume, cc/gm 851	Vapor Pressure: <u>°C</u> <u>mm Mercury</u> 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 glycol 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 Vigreux fractionating 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 $0 \pm 5^\circ C$. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at $0 \pm 5^\circ C$, 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 ethereal 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: 78

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

<u>3</u>	<u>2</u>	<u>6</u>	<u>7</u>	<u>8</u>
1953	1745	1786	1767	1638
2193		2056	1817	

⁷⁸See footnote 1, page 10.

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Trinitroite

Composition: % Picric Acid 88 - Mononitronaphthalene 12 10 C/H Ratio	Molecular Weight: 217	
	Oxygen Balance: CO ₂ % -62 CO % -14	
	Density: gm/cc	Cast 1.60
	Melting Point: °C 90	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 10 Sample Wt, mg	Boiling Point: °C Explodes 300	
	Refractive Index, n _D ²⁰ n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 0.9 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % 0 Partial 0 Turned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm 44.2	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 315 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.04	
	Ballistic Mater., % TNT:	
	Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7020	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Trimonite

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Principal Uses: TNT substitute in projectiles and bombs
Fragment Velocity: ft/sec At 9 ft At 25 1/4 ft Density, gm/cc	Method of Loading: Cast Loading Density: gm/cc 1.60
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: <div style="display: flex; justify-content: space-around;"> Method Dry </div> <div style="display: flex; justify-content: space-around;"> Hazard Class (Quantity-Distance) Class 9 </div> <div style="display: flex; justify-content: space-around;"> Compatibility Group Group I </div> <div style="display: flex; justify-content: space-around;"> Exudation Bubbles at 50°C </div> Preparation: Picric acid and alpha-mononitronaphthalene are melted together in an aluminum or tin steam-jacketed melt kettle equipped with a stirrer. Although picric acid alone requires a high temperature for its melt loading (120°C), the mixture forms a eutectic melting at 49°C. Care must be taken to prevent the formation of dangerous metallic picrates. Trimonite is of interest as an emergency substitute for TNT.

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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: ⁷⁹

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

<u>2</u>	<u>2</u>	<u>6</u>	<u>8</u>
1352	1325	926	1098
1372		976	1838

⁷⁹See footnote 1, page 10.

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

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Composition: % C 18.6 H 1.6 N 21.8 O 58.0 C/H Ratio 0.202	<div><div>O-CH₂C(NO₂)₃</div><div>C = O</div><div>CH₂CH₂C(NO₂)₃</div></div>	Molecular Weight: (C ₆ H ₅ N ₆ O ₁₄) 386
		Oxygen Balance: CO ₂ % -4.2 CO % 20.8
		Density: gm/cc Form I 1.78
		Melting Point: °C 93
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 50% point, cm (a) 20		Boiling Point: °C
		Refractive Index, n_D²⁰ Form I (e) <u>Crystal Axis</u> a 1.518 β 1.527 T 1.546
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 48 hrs 0.60 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point (Alhot bar) (a) 225 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: (b) 136
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Tressal Test, % TNT:
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Hygroscopicity: % 30°C, 90% RH 0.00 75°C, 5 months Nil (a)		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.60 1.76 Rate, meters/second 7760 8293
Volatility:		

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2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec 4.4×10^{21} (Z/sec) Heat, kilocalorie/mole 43.4 (ΔH , kcal/mol) Temperature Range, °C Phase Liquid
Heat of: Combustion, cal/gm 1685 Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm 307 Fusion, cal/gm Sublimation, cal/gm (est) 804	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1 1/4 1 1/2 1 3/4
Specific Heat: cal/gm/°C	Bomb Drop Test: 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
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² E, lb/inch ² Density, gm/cc	
Compressive Strength: lb/inch ²	
Vapor Pressure: (e) °C mm Mercury 65 3.3×10^{-4} 75 1.3×10^{-4} 85 4.2×10^{-5} 100 2.3×10^{-3} 120 1.4×10^{-2}	

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2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)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

TNETB Forms Eutectics With the Following Compounds:

(a)

TNT	57
BINES (bis(trinitroethyl) succinate)	80+
BIVEN (bis(trinitroethyl) nitramine)	68.5
TNB (trinitrobenzene)	65
Compound A ($C_4H_6N_4O_8$, formed by condensation of 1,1-dinitroethane)	77
Trinitroethyl trinitrobenzoate (27%)	80.5 (r)

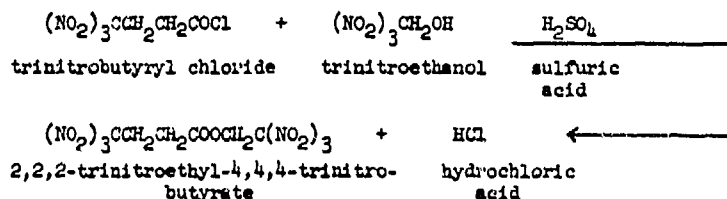
Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°C giving Form II. Form II has a melting point of 92.5° to 93°C. On cooling, Form II does not transform reversibly to Form I when 89°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° to 0.3°C near 92.5°C.

Preparation:

(a)



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 H_2SO_4 , the ester can be prepared in yields of 95% to 98% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°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° to 93°C.

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

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Origin:

(e)

TNETB 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 Schimmelschmidt, 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. Schimmelschmidt 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 TNETB, considerable interest was aroused. In early 1950 the Naugatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TNETB. The Bureau of Ordnance in July 1953 raised the production to 800 pounds with the assistance of the Hercules Powder Company in augmenting the production at Naugatuck (Navy Contract NORD-11,280). TNETB is a high oxygen content explosive.

References: 80

(a) J. M. Rosen, Properties of Trinitroethyl Trinitrobutyrate TNETB, NAVORD Report No. 1758, 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. Svadaba, Evaluation of 2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate as a Constituent of Castable Explosives, NAVORD Report No. 2614, 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 TNETB, 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.

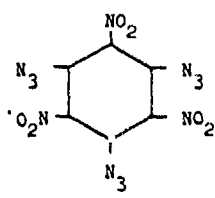
(g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, NAVORD Report No. 2997, 22 October 1953.

(h) R. W. Gipson, Sensitivity of Explosives, IX. Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

⁸⁰See footnote 1, page 10.

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Trinitro Triazidobenzene

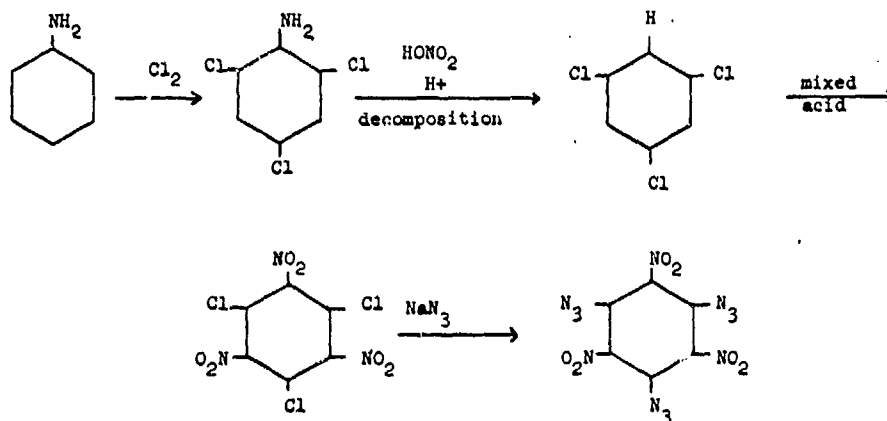
Composition: %		Molecular Weight: (C ₆ O ₆ N ₁₂)	336
C	21.4	Oxygen Balance:	
N	50.0	CO ₂ %	-29
O	28.6	CO %	0.0
		Density: gm/cc	Crystal 1.81
C/H Ratio		Melting Point: °C	Decomposes 131
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm (a) ≤ 25 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Freezing Point: °C	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Boiling Point: °C	
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected		Refractive Index, n_D²⁰ n _D ²⁰ n _D ²⁵	
Explosion Temperature: °C (a) Seconds, 0.1 (no cap used) -- 1 -- 5 150 10 15 20		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
75°C International Heat Test: % Loss in 48 Hrs		200 Gram Bomb Sand Test: Sand, gm	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
Flammability Index:		Ballistic Mortar, % TNT:	
Hygroscopicity: % 30°C, 90% RH 0.00		Trauzl Test, % PETN:	90
Volatility:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

Trinitro Triazidobenzene

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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, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth Color: Greenish-yellow Principal Uses: (c) Ingredient of primer mix Method of Loading: Pressed Dead presses at about 42,000 psi										
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Loading Density: gm/cc At 42,000 psi 1.75										
Blust (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation None <u>Qualitative Solubilities</u> <u>at Room Temperature:</u> <table> <tr> <th><u>Solvent</u></th><th><u>Solubility</u></th></tr> <tr> <td>Acetone</td><td>Readily soluble</td></tr> <tr> <td>Chloroform</td><td>Moderately soluble</td></tr> <tr> <td>Alcohol</td><td>Springly soluble</td></tr> <tr> <td>Water</td><td>Insoluble</td></tr> </table> <u>Compatibility with Metals:</u> <u>Wet:</u> Does not attack iron, steel, copper or brass. <u>Heat of:</u> Combustion, cal/gm (a) 2554 <u>Burning Rate:</u> (b) cm/sec 0.65	<u>Solvent</u>	<u>Solubility</u>	Acetone	Readily soluble	Chloroform	Moderately soluble	Alcohol	Springly soluble	Water	Insoluble
<u>Solvent</u>	<u>Solubility</u>										
Acetone	Readily soluble										
Chloroform	Moderately soluble										
Alcohol	Springly soluble										
Water	Insoluble										

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Trinitro TriazidobenzenePreparation: (e)

Aniline is chlorinated to form trichloroaniline. The amino group is eliminated by the diazo reaction. The resulting sym-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:⁸¹

(a) S. Helf, 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.

⁸¹See footnote 1, page 10.

Tripentaerythritol Octanitrate (TPEON)

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Composition: % C 24.6 H 3.3 N 15.3 O 56.8 $\begin{array}{c} \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \\ \quad \quad \\ \text{O}_2\text{NOCH}_2\text{CCH}_2\text{OCH}_2\text{CCH}_2\text{OCH}_2\text{CCH}_2\text{ONO}_2 \\ \quad \quad \\ \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \quad \text{CH}_2\text{ONO}_2 \end{array}$ C/H Ratio 0.175	Molecular Weight: ($\text{C}_{15}\text{H}_{24}\text{N}_8\text{O}_{26}$) 732	
	Oxygen Balance: CO ₂ % -35 CO % -2.2	
	Density: gm/cc	Crystal 1.58
	Melting Point: °C 82 to 84	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 24	Freezing Point: °C	
	Boiling Point: °C	
	Refractive Index, n_D^{20} n_D^{20} n_D^{20}	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C Pure 2.45 120°C Specially purified 1.94 135°C 150°C	
	200 Gram Bomb Sand Test: Sand, gm 58.9	
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 225 10 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
	Ballistic Mortar, % TNT: Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	Plate Drop Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 1.15 % Loss, 2nd 48 Hrs 0.75 Explosion in 100 Hrs None	Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.56 Rate, meters/second 7650	
Flammability Index:		
Hygroscopicity: %		
Volatility:		

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Tripentaerythritol Octanitrate (TPEON)

Beester Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	23.1 215 to 250 Liquid
Specific Heat: cal/gm/°C Specific Impulse: lb-sec/lb (calculated)	Armer Plate Impact Test: 66 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bombs: Plate Thickness, inches 1 1¼ 1½ 1¾
Burning Rate: cm/sec	Bomb Drop Test: T7, 2000-lb Semi-Armer-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
Thermal Conductivity: cal/sec/cm/°C	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm² E, lb/inch² Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure: °C mm Mercury	

Tripentaerythritol Octanitrate (TPEON)

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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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: Glass Cones Steel Cones Hole Volume Hole Depth																																							
	Color: White																																							
	Principal Uses: High explosive and as possible plasticizer for nitrocellulose																																							
	Method of Loading: Cast or pressed																																							
	Loading Density: gm/cc Pressed at 60,000 psi 1.565																																							
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None																																							
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Hygroscopicity, Gain or Loss in Wt, %: <table><tr><th rowspan="2">Time, Hrs</th><th colspan="3">% RH at 30°C</th></tr><tr><th>40</th><th>70</th><th>90</th></tr><tr><td>24</td><td>-0.008</td><td>+0.01</td><td>+0.04</td></tr><tr><td>48</td><td>-0.02</td><td>-0.01</td><td>+0.02</td></tr><tr><td>144</td><td>-0.04</td><td>-0.03</td><td>-0.02</td></tr><tr><td>192</td><td>-0.04</td><td>-0.02</td><td>-----</td></tr><tr><td>216</td><td>-0.004</td><td>-0.01</td><td>+0.03</td></tr></table> Solubility: <table><tr><th>Solvent</th><th>Solubility</th></tr><tr><td>Water</td><td>Insoluble</td></tr><tr><td>Alcohol</td><td>Soluble</td></tr><tr><td>Chloroform</td><td>Soluble</td></tr><tr><td>Acetone, hot</td><td>Very soluble</td></tr><tr><td>Benzene, hot</td><td>Very soluble</td></tr></table>	Time, Hrs	% RH at 30°C			40	70	90	24	-0.008	+0.01	+0.04	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	Solvent	Solubility	Water	Insoluble	Alcohol	Soluble	Chloroform	Soluble	Acetone, hot	Very soluble	Benzene, hot	Very soluble
Time, Hrs	% RH at 30°C																																							
	40	70	90																																					
24	-0.008	+0.01	+0.04																																					
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																																					
Solvent	Solubility																																							
Water	Insoluble																																							
Alcohol	Soluble																																							
Chloroform	Soluble																																							
Acetone, hot	Very soluble																																							
Benzene, hot	Very soluble																																							

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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	0.11	2.15	0.39	2.45
ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE	1.89	1.71	2.32	—

Dipentaerythritol Hexanitrate (DPEHN)-TPEON Fusions:

% TPEON	% DPEHN	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 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:⁸²

- (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. Namba, J. Yamashita and S. Tanaka, "Pentaerythritol Tetranitrate," J Ind Explosives Soc (Japan) 15, 282-9 (1954); CA 49, 11283 (1955).
- (c) S. D. Brewer and H. Henkin, The Stability of PETN and Pentolite, OSRD Report No. 1414.
- (d) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

⁸²See footnote 1, page 10.

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Tritonal, 80/20

Composition: % TNT 80 Aluminum 20 C/H Ratio	Molecular Weight: 81	
	Oxygen Balance: CO ₂ % -77 CO % -38	
	Density: gm/cc	Cast 1.72
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 85 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 16	Boiling Point: °C	
	Refractive Index, n_D²⁰	
	n _D ²⁵ n _D ³⁰	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.1 120°C 0.2 135°C -- 150°C 0.8	
	200 Gram Bomb Sand Test: Sand, gm	
Rifle Bullet Impact Test: Trials % Explosions 60 Partials 0 Burned 0 Unaffected 40	Explosion Temperature: °C Seconds, 0.1 (no cap used) 610 1 520 5 Decomposes 470 10 465 15 20	
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 124	
	Trauzl Test, % TNT: (b) 125	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: (c) Method B Condition Cast Confined No Density, gm/cc 1.75 Brisance, % TNT 93	
	Detonation Rate: Confinement None None Condition Cast Pressed Charge Diameter, in. 1.0 1.0 Density, gm/cc 1.71 1.72 Rate, meters/second 6475 6700	
Flammability Index: 100		
Hygroscopicity: % 30°C, 90% RH 0.00		
Volatility:		

Tritonal, 80/20

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Booster Sensitivity Test: (d) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 0.58 Wax, gm Density, gm/cc 1.75	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, °C Phase
Heat of: (c) Combustion, cal/gm 4480 Explosion, cal/gm 1770 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: (e) 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec 509 >1100 Aluminum Fineness 100 12 500-lb General Purpose Bomb: Plate Thickness, inches Trials % Inert 1 0 1¼ 6 100 1½ 6 33 1¾ 0
Specific Heat: cal/g·°C (b) At -5°C 0.23 Density, gm/cc 1.74 At 20°C 0.31	Bomb Drop Test: (e) T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: Height, ft Seal 4,000 Seal 5,000 Trials 34 14 Unaffected 32 14 Low Order 0 0 High Order 2 0
Burning Rate: cm/sec	1000-lb General Purpose Bomb vs Concrete: Height, ft Seal 5,000 Trials 24 Unaffected 23 Low Order 0 High Order 1
Thermal Conductivity: cal/sec/cm/°C (b) 11×10^{-4} Density, gm/cc 1.73	
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: (b) E, dynes/cm² 6.67×10^{10} E, lb/inch² 0.97×10^6 Density, gm/cc 1.72	
Compressive Strength: lb/inch² (b) 2340 Density, gm/cc 1.75	
Vapor Pressure: °C mm Mercury	

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Tritonal, 80/20

Fragmentation Test: 90 mm HE, M71 Projectile, Lot WC-91: Density, gm/cc 1.71 Charge Wt, lb 2.272 Total No. of Fragments: For TNT 703 For Subject HE 616 3 inch HE, M42A1 Projectile, Lot KC-3: Density, gm/cc 1.73 Charge Wt, lb 0.914 Total No. of Fragments: For TNT 514 For Subject HE 485	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth Color: Gray Principal Uses: GP bombs Method of Loading: Cast Loading Density: gm/cc 1.65-1.72
Fragment Velocity: ft/sec At 9 ft 2460 At 25½ ft 2380 Density, gm/cc 1.72	Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Exudation
Blast (Relative to TNT): (f) 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	Preparation: 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.

Tritonal, 80/20

AMCP 706-177

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:⁸³

- (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 HBX 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. 4649, Division 2, Monthly Report No. AES-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).

⁸³See footnote 1, page 10.

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Tritonal, EO/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						

Veltex No. 448*

AMCP 706-77

Composition:		Molecular Weight:		281
%		Oxygen Balance:		
HMX	70.0	CO ₂ %		-26
Nitrocellulose (13.15% N)	15.0	CO %		-0.5
Nitroglycerin	10.7	Density: gm/cc		Pressed 1.72
2-Nitrodiphenylamine	1.3	Melting Point: °C		
Triacetin	3.0	Freezing Point: °C		
C/H Ratio		Boiling Point: °C		
Impact Sensitivity, 2 Kg Wt:		Refractive Index, n_D²⁰		
Bureau of Mines Apparatus, cm		n _D ²⁰		
Sample Wt 20 mg		n _D ²⁰		
Picatinny Arsenal Apparatus, in.				
Sample Wt, mg				
Friction Pendulum Test:		Vacuum Stability Test:		
Steel Shoe	Unaffected	cc/40 Hrs, at		
Fiber Shoe	Unaffected	90°C		----
Rifle Bullet Impact Test:		100°C		1.29
Trials	%	120°C 29 hours		11+
Explosions		135°C		
Partials		150°C		
Burned		200 Gram Bomb Sand Test:		
Unaffected		Sand, gm		66.4
Explosion Temperature: °C		Sensitivity to Initiation:		
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm		
1		Mercury Fulminate		----
5		Lead Azide		0.30
10		Tetryl		----
15		Ballistic Mortar, % TNT:		
20		Treuzl Test, % TNT:		
75°C International Heat Test:		Plate Dent Test:		
% Loss in 48 Hrs		Method		
90°C Heat Test:		Condition		
% Loss, 1st 48 Hrs	0.28	Confined		
% Loss, 2nd 48 Hrs	1.12	Density, gm/cc		
Explosion in 100 Hrs	None	Brisance, % TNT		
Flammability Index:		Detection Rate:		
Hygroscopicity: %		Confinement		
Volatility:		Condition		
		Charge Diameter, in.		
		Density, gm/cc		
		Rate, meters/second (calculated)		8500

*See footnote on following page.

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Valtex No. 448*

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH , kcal/mol) Temperature Range, °C Phase
Heat of: Combustion, cal/gm 2359 Explosion, cal/gm 1226 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test: 60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness 500-lb General Purpose Bomb: Plate Thickness, inches 1 1½ 1¾ 1⅞
Compression at Rupture: % 8.26 <u>Work to Produce Rupture:</u> ft-lb/inch ³ 9.62	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C	Bomb Drop Test: 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
Coefficient of Expansion: Linear, %/°C Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E', dynes/cm ² 0.24×10^{10} E, lb/inch ² 0.35×10^5 Density, gm/cc	1000-lb General Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order High Order
Compressive Strength: lb/inch ² 2720	
Vapor Pressure: °C mm Mercury	
*Name assigned by Dr. Mark M. Jones, formerly of PA; based on original development by James H. Veltman.	

Veltex No. 449

AMCP 706-177

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, M42A1 Projectile, Lot KC-3: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE	Shaped Charge Effectiveness, TNT = 100: <div style="display: flex; justify-content: space-around;"> Glass Cones Steel Cones </div> Hole Volume Hole Depth
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	Color: Orange
Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy	Principal Uses: High mechanical strength machinable explosive
	Method of Loading: Pressed
	Loading Density: gm/cc At 6,700 psi 1.72
	Storage: Method Dry Hazard Class (Quantity-Distance) Compatibility Group Exudation None Machinability Excellent

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Veltex No. 448Preparation:

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 colloid is then preheated on a heat table at 66°C. Increments of 25 gm each are pressed at 6700 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 diethyleneglycol 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:⁸⁴

- (a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

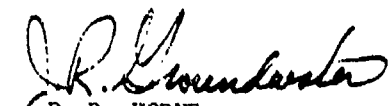
⁸⁴See footnote 1, page 10.

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(AMCRD-TV)

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OFFICIAL:


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Colonel, GS

Chief, HQ Admin Mgt Ofc

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128(S)	*Infrared Military Systems, Part Two (U)	247	Ammunition, Section 4, Design for Projection
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