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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:

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

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Washington, D. C. 20310

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

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

ABBREVIATIONS AND SYMBOLS

~	approximately. This symbol is used before numbers.
AC	Advisory Council on Scientific Research and Development, Great Britain.
ACS	American Chemical Society.
AISI	American Iron and Steel Institute.
Ann	Liebig's Annalen der Chemie.
Ann chim phys	Annales de chimie et de physique.
AP	armor-piercing.
APG	Aberdeen Proving Ground.
atm	atmosphere; atmospheric pressure.
Beil	Beilstein Organische Chemie, 4th Edition.
Ber	Berichte der Deutschen Chemischen Gesellschaft.
BIOS GP2-HEC	British Intelligence Overseas Service or Objective Subcommittee, Group 2, Halstead Exploiting Center.
BM	Bureau of Mines, United States Department of Interior.
Bull Soc chim	Bulletin de la societé chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
dec	decomposes.
ΔH	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
E	modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in $lb/inch^2$.
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 Physikalish-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_{20}^{D}	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	Poggendorf's Annalen der Physik.
Proc Roy Soc	Proceedings of the Royal Society of London.
Rec trav chim	Recueil des travaux chimiques des Pays-Bas.
RH	relative humidity.
RI	Report of Investigation.
SAE	Society of Automotive Engineers.
SAP	semi-armor-piercing.
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 Sprengstoffwessen (Munchen).
Z/sec	atoms of oxygen per second.

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

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

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

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

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

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "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.

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

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

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

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

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

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

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

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

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

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

(6) "Explosion Temperature." (a)

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

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

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

(8) "100°C Heat Test." (a)

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

(9) "Flammability Index." (h)

The measure of the likelihood that 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

$$\text{MW of mixture} = \frac{100}{\frac{a}{mw_1} + \frac{b}{mw_2} + \frac{c}{mw_3} + \frac{n}{mw_n}}$$

where a, b, c and n are the weight percents of the components, and mw_1, mw_2, mw_3 and mw_n their corresponding molecular weights.

(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:

$$\text{Metal} + O \longrightarrow \text{Metal Oxide}$$

$$C + H_2O \longrightarrow CO + H_2$$

$$CO_2 + H_2 \longrightarrow CO + H_2O$$

$$2CO + O_2 \longrightarrow 2CO_2$$

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

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

$\div$ 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:

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

(14) "Density."

(15) "Melting Point."

(16) "Freezing Point."

(17) "Boiling Point."

(18) "Refractive Index."

(19) "Vacuum Stability Test." (a)

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

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

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

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

(b) Sand test for liquids. (b)

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

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

(21) "Sensitivity to Initiation."

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

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

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

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

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

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

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is cast in a mold from desilverized lead of the best quality. Although these tests have been made under a variety of conditions, where possible the data have been taken from or related to those of Reference f (Naoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions of Naoum's test. Thus expansions for equivalent weights were readily calculated, and the test value expressed in percent of the expansion of an equivalent weight of TNT.

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

Two methods were used for plate dent tests.

(a) Method A - The charge is contained in a copper tube, having an internal diameter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a horizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate, and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered 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 Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

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

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc (for low loading density), or the Boas, approximately 45 cc (for high loading density). For heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

(3) "Specific Heat."

(4) "Burning Rate."

(5) "Thermal Conductivity."

(6) "Coefficient of Expansion."

(7) "Hardness, Mohs' Scale."

(8) "Young's Modulus."

(9) "Compressive Strength."

(10) "Vapor Pressure."

(11) "Decomposition Equation."

(12) "Armor Plate Impact Test." (J)

(a) 60-mm Mortar Projectile.

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

(b) 500-lb General Purpose Bombs.

(13) "Bomb Drop Test."

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

c. Third tabular page.

(1) "Fragmentation Test." (1)

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

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

(2) "Fragment Velocity."

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

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

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

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

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

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. 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).

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-weighed 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electromatic pH method.

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

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

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

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

(7) Destruction by chemical decomposition.

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

(8) Other information.

(9) References.

6. REFERENCES CITED IN INTRODUCTION.[1]

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

g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.

h. NDRC Interim Report, Preparation and Testing of Explosives, Nos. PT-19 and PT-20, February-April 1944.

i. Linnie E. Newman, PA Chemical Laboratory Report Nos. 127815 and 134476, 11 January 1951.

j. Report AC-2983/Org Expl 179.

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

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.

Amatol, 80/20

Composition:

%	
Ammonium Nitrate	80
TNT	20

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	90
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 5 Trials

	%
Explosions	0
Partials	0
Burned	0
Unaffected	100

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	Decomposes 280
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs	0.06

100°C Heat Test:

% Loss, 1st 48 Hrs	0.03
% Loss, 2nd 48 Hrs	0.05
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

30°C, 90% RH, 2 days	61

Volatility: Nil

Molecular Weight: 92

Oxygen Balance:

CO_2 %	+1
CO %	+11

Density: gm/cc Cast 1.46

Melting Point: °C

Freezing Point: °C

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

200 Gram Bomb Sand Test:

Sand, gm	35.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.07

Ballistic Mortar, % TNT: (a) 130

Trauzl Test, % TNT: (b) 123

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement	None	None
Condition	Cast	Cast
Charge Diameter, in.	1.0	1.0
Density, gm/cc	1.46	[illegible]
Rate, meters/second	4500	5100

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	(f)
At 9 ft	1900
At 25½ ft	1750
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: Buff-yellow

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)
Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	0.83
Density, gm/cc	1.65

Heat of:	(d, e)
Combustion, cal/gm	1002*
Explosion, cal/gm	490*
Gas Volume, cc/gm	930*

*Calculated from composition of mixture.

Amatol, 60/40

Composition:		
%		
Ammonium Nitrate		60
TNT		40
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		95
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		16
Sample Wt, mg		17
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 270	
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		
Flammability Index:		
Hygroscopicity: %		
Volatility:		Nil

Molecular Weight:		108
Oxygen Balance:		
CO_2 %		-18
CO %		+ 2
Density: gm/cc	Cast	1.60
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		41.5
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.06
Ballistic Mortar, % TNT:	(a)	128
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.50
Rate, meters/second		5760

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.49
Charge Wt, lb	1.971

Total No. of Fragments:

For TNT	703
For Subject HE	583

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.57
Charge Wt, lb	0.827

Total No. of Fragments:

For TNT	514
For Subject HE	408

Fragment Velocity: ft/sec

At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:

Peak Pressure	95
Impulse	85
Energy	84

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: Buff-yellow

Principal Uses: Bombs, HE projectiles

Method of Loading: Cast

Loading Density: gm/cc 160

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

Heat of: (d, e)

Combustion, cal/gm	1658*
Explosion, cal/gm	633*
Gas Volume, cc/gm	880*

*Calculated from composition of mixture.

Amatol, 50/50

Composition:

%	
Ammonium Nitrate	50
TNT	50

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	95
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	16
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

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 265
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

Flammability Index:

Hygroscopicity: % Nil

Volatility:

Molecular Weight: 118

Oxygen Balance:

CO_2 %	-27
CO %	- 3

Density: gm/cc Cast 1.59

Melting Point: °C

Freezing Point: °C

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	0.2
120°C	1.0
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 42.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.05

Ballistic Mortar, % TNT: (a) 124

Trauzl Test, % TNT:

Plate Dent Test:

Method	B
Condition	Cast
Confined	No
Density, gm/cc	1.55
Brisance, % TNT	52

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

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

Fragment Velocity: ft/sec

At 9 ft
At 25½ ft
Density, gm/cc

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

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

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

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

Compatibility with Metals:

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

Preparation:

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

0	1	2	3	4	5	6	7	8	9
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	734	695	666	1797	838	929
950	1051	1352	1323	874	715	986	1827	1098	1129
1300	1311	1372	1493	1344	735	1376	2167	1148	1219
1530	1451	1552	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.

[2]See footnote 1, page 10.

Composition:	
%	
Ammonium Nitrate	22
TNT	67
Aluminum	11
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	91
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	19
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 265	
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.10
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:	102
Oxygen Balance:	
CO_2 %	-55
CO %	-22
Density: gm/cc Cast	1.65
Melting Point: °C	
Freezing Point: °C	
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	
120°C	4.4
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	47.8
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.20
Lead Azide	
Tetryl	
Ballistic Mortar, % TNT: (a)	122
Trauzl 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	

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	1.65
Charge Wt, lb	

Total No. of Fragments:

For TNT	655
For Subject HE	550

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	

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.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Projectile filler

Method of Loading: Cast

Loading Density: gm/cc 1.65

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Origin:

Castable mixture developed in United States during World War I.

References:

(a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.

(b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.

Ammonium Nitrate

Composition:

%		
N	35	
H	5	NH_4NO_3
O	60	
C/H Ratio		

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	31
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	0
Burned	0
Unaffected	100

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		
1		
5	Ignites	465
10		
15		
20		

75°C International Heat Test: (a)

% Loss in 48 Hrs	0.0

100°C Heat Test:

% Loss, 1st 48 Hrs	0.74
% Loss, 2nd 48 Hrs	0.13
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %
30°C, 90% RH — Extreme

Volatility: Decomposes at 210°C

Molecular Weight: ($H_4N_2O_3$) 80

Oxygen Balance:

CO_2 %	+20
CO %	+20

Density: gm/cc Crystal 1.73

Melting Point: °C 170

Freezing Point: °C

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	0.3
135°C	
150°C	0.3

200 Gram Bomb Sand Test:

Sand, gm	Nil

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.25

Ballistic Mortar, % TNT: (a) 56

Trauzl Test, % TNT:

Plate Dent Test:

Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

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

Booster Sensitivity Test:
- Condition
- Tetryl, gm
- Wax, in. for 50% Detonation
- Wax, gm
- Density, gm/cc

Heat of:

Combustion, cal/gm	346
Explosion, cal/gm	346
Gas Volume, cc/gm	980
Formation, cal/gm	1098
Fusion, cal/gm	18.23

Specific Heat: cal/gm/°C (e)

°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 $2.9\text{-}3.9 \times 10^{-4}$

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: (g)

°C	mm Mercury
188	3.25
205	7.45
216	11.55
223	15.80
237	27.0
249	41.8

Decomposition Equation:

	(f)	(h)
Oxygen, atoms/sec (Z/sec)	$10^{13.8}$	$10^{12.3}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	40.5	38.3
Temperature Range, °C	243-261	217-267
Phase	Liquid	

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

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

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: Colorless

Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles

Method of Loading: Pressed or cast depending on composition of mixture.

Loading Density: gm/cc Variable

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 12
Compatibility Group	Group D
Exudation	None

Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b)

Temp. °C	PA Impact Test 2 Kg Wt, inches
25	31
75	28
100	27
150	27
175	12

Compatibility with Metals: (a)

In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.

Entropy: (g)

cal/mol at 25°C 36.0

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

Water		Alcohol		Acetic Acid		Nitric Acid			Pyridine	
°C	%	°C	%	°C	%	°C	%	% Nitric Acid	°C	%
0	118	20	2.5	16.6	0.0	0	45.1	30.0	25	~20-25
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 alkalies 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. Gamow, 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.

[3]See footnote 1, page 10.

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

0	1	2	3	4	5	6	7	8	9
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	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				

Ammonium Perchlorate

Composition: %	**Molecular Weight:** (ClH_4NO_4) 117.5
Cl 30.2	**Oxygen Balance:** CO_2 % +27.3; CO % +27.3
N 11.9 — NH_4ClO_4	**Density:** gm/cc 1.95
H 3.4	**Melting Point:** °C
O 54.5	**Freezing Point:** °C
C/H Ratio	**Boiling 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	**Refractive Index,** n_D^{20}, n_D^{25}, n_D^{30}
Friction Pendulum Test: Steel Shoe: Snaps; Fiber Shoe: Unaffected	**Vacuum Stability Test:** cc/40 Hrs, at 90°C; 100°C 0.13; 120°C 0.20; 135°C; 150°C 0.32
Rifle Bullet Impact Test: Trials %; Explosions; Partials; Burned; Unaffected	**200 Gram Bomb Sand Test:** Sand, gm 6.0
Explosion Temperature: °C; Seconds, 0.1 (no cap used); 1; 5 435; 10; 15; 20	**Sensitivity to Initiation:** Minimum Detonating Charge, gm; Mercury Fulminate; Lead Azide 0.20; Tetryl 0.25
	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 0.02; % Loss, 2nd 48 Hrs 0.00; Explosion in 100 Hrs None	
Flammability Index:	**Detonation Rate:** Confinement; Condition; Charge Diameter, in.; Density, gm/cc; Rate, meters/second
Hygroscopicity: %	
Volatility:	

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: 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

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

Solubility in Water
gm/100 cc saturated solution:

0°C	12
25°C	20
60°C	39
100°C	88

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

Ammonium Perchlorate

Origin: (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, Longmanns, Green and Co., London, 1922, p. 396.

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

0	1	3	4	5	6	9
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

[4]See footnote 1, page 10.

Composition:	
%	
Barium nitrate	67
TNT	33
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	35
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	24
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 Ignites	385
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	
Flammability Index:	
Hygroscopicity: %	
30°C, 90% RH	0.00
Volatility:	

Molecular Weight:	125
Oxygen Balance:	
CO_2 %	-3
CO %	+13
Density: gm/cc Cast	2.55
Melting Point: °C	
Freezing Point: °C	
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	
120°C	
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	26.8
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.10
Ballistic Mortar, % TNT:	
Trauzl Test, % TNT:	
Plate Dent Test: (a)	73/27
Method	B
Condition	Cast
Confined	No
Density, gm/cc	2.52
Brisance, % TNT	61
Detonation Rate:	
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	
Rate, meters/second	

Booster Sensitivity Test:

Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	0.32
Wax, gm	
Density, gm/cc	2.55

Heat of:

Combustion, cal/gm		
Explosion, cal/gm		
Gas Volume, cc/gm		
Formation, cal/gm		
Fusion, cal/gm 75/25 Baratol	2.8	(d)

Specific Heat: cal/gm/°C (d) 75/25 Baratol

°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, Mohs' Scale:

Young's Modulus:
E', dynes/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure:
°C mm Mercury

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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:

Principal Uses: Bomb filler

Method of Loading: Cast

Loading Density: gm/cc 2.55

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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.

References:[5]

(a) D. P. MacDougall, Methods of Physical Testing, OSRD 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, OSRD Report No. 5746, 27 December 1945.

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

0	3	6	8
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.

[5]See footnote 1, page 10.

Baronal

Composition:		
	%	
Barium nitrate	50	
TNT	35	
Aluminum	15	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		30
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		12
Sample Wt, mg		22
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 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		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Molecular Weight:		111
Oxygen Balance:		
CO_2 %		-24
CO %		-7
Density: gm/cc		2.32
Melting Point: °C		
Freezing Point: °C		
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		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		39.8
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.10
Ballistic Mortar, % TNT:	(a)	96
Trauzl Test, % TNT:		
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

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

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:

Principal Uses: Bomb filler

Method of Loading: Cast

Loading Density: gm/cc 2.32

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

Preparation:

Procedure same as described under Baratol except aluminum is added to the barium nitrate-TNT molten mixture under agitation until uniformity in comparison is obtained.

Booster Sensitivity Test:

	(c)
Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	0.86
Density, gm/cc	2.32

Heat of:

Combustion, cal/gm	2099
Explosion, cal/gm	1135
Gas Volume, cc/gm	410

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.

[6]See footnote 1, page 10.

Black Powder

Composition: %		
Potassium nitrate	74.0	
Sulfur	10.4	
Charcoal	15.6	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	32	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	16	
Sample Wt, mg	16	
Friction Pendulum Test:		
Steel Shoe	Snaps	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions		
Partials		
Burned		
Unaffected		
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	510	
1	490	
5 Ignites	427	
10	356	
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		0.31
100°C Heat Test:		
% Loss, 1st 48 Hrs		
% Loss, 2nd 48 Hrs		
Explosion in 100 Hrs		
Flammability Index:		
Hygroscopicity: %	25°C, 75% RH	0.75
	25°C, 90% RH	1.91
	30°C, 90% RH	2.51
Volatility:		

Molecular Weight:	84
Oxygen Balance:	
CO_2 %	-22
CO %	- 2
Density: gm/cc	Variable
Melting Point: °C	
Freezing Point: °C	
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	0.5
120°C	0.9
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	8
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	
Tetryl	
Sensitive to igniting fuse	
Ballistic Mortar, % TNT:	50
Trauzl Test, % TNT: (a)	10
Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detonation Rate:	
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.6
Rate, meters/second	400

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

Initiating Efficiency:

Grams Required to Initiate

Igniter Comp K-31	2.0
Igniter Comp K-29	2.3

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Black

Principal Uses:
1. Igniter powder
2. Time rings (fuzes)

Method of Loading:
1. Loose (granulated)
2. Pressed

Loading Density: gm/cc

psi x 10^3	25	50	60	65	70	75
gm/cc	1.74	1.84	1.86	1.87	1.88	1.89

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group O
Exudation	None

100°C Vacuum Stability Test, cc gas/40 hrs:

Initial Value	0.5
After 2 hours at 65°C	0.86
After 2 hours at 65°C, 75% RH	1.46

Sensitivity to Electrostatic Discharge, Joules: (b)

Unconfined	>12.5
Confined	0.8

Compatibility with Metals:

Dry - Compatible with all metals when moisture content is less than 0.20%.

Wet - Attacks all common metals except stainless steel.

Heat of:

Explosion, cal/gm	684
Gas Volume, cc/gm	271

Black Powder

Preparation:

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

WARNING

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

Origin:

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

Destruction by Chemical Decomposition:

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

References:[7]

(a) Ph. Naoum, 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:

[7] See footnote 1, page 10.

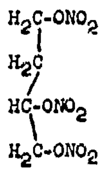
Black Powder

0	1	2	3	4	5	6	7	8	9
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	

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

Composition:

%	
C	19.9
H	2.9
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.	≤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: % (a)	
100°F, 95% RH, 24 hrs	0.14
Volatility:	
60°C, mg/cm²/hr	46

Molecular Weight: ($C_4H_7N_3O_9$)	241
Oxygen Balance:	
CO_2 %	-17
CO %	10
Density: gm/cc Liquid	1.52
Melting Point: °C	
Freezing Point: °C	
Boiling Point: °C	
Refractive Index, n_{20}^{D}	1.4738
n_{25}^{D}	
n_{30}^{D}	
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:	
Trauzl 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	

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

Heat of:	(a)
Combustion, cal/gm	2168
Explosion, cal/gm	1457
Gas Volume, cc/gm	840

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Yellow oil

Principal Uses: Explosive plasticizer for nitrocellulose

Method of Loading:

Loading Density: gm/cc 1.52

Storage:

Method

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

Solubility in Water, gm/100 gm, at:	(a)
20°C	0.08
60°C	0.15

Solubility of Water in, gm/100 gm:	(a)
	0.04

Solubility, gm/100 gm, at 25°C, in:	
Ether	∞
Alcohol	∞
2:1 Ether:Alcohol	∞
Acetone	∞

Viscosity, centipoises:	(a)
Temp. 25°C	59

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

Preparation (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. Gallaghan, 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.

[8] See footnote 1, page 10.

Composition:

%	
RDX	91
Wax	9

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	16
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

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	250
10		
15		
20		

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.15
% Loss, 2nd 48 Hrs	0.15
Explosion in 100 Hrs	None

Flammability Index: 195

Hygroscopicity: % 30°C, 90% RH 0.0

Volatility: 50°C, 15 days 0.03

Molecular Weight: 227

Oxygen Balance:

CO_2 %	-48
CO %	-23

Density: gm/cc 12,000 psi 1.65

Melting Point: °C

Freezing Point: °C

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	0.6
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 51.5

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	0.22*
Lead Azide	0.25*
Tetryl	

* Alternative initiating charges

Ballistic Mortar, % TNT: (a) 135

Trauzl Test, % TNT:

Plate Dent Test: (b)

Method	B	B
Condition	Pressed	Pressed
Confined	No	No
Density, gm/cc	1.61	1.20
Brisance, % TNT	126	75

Detonation Rate: (c)

Confinement	None
Condition	Pressed
Charge Diameter, in.	1.0
Density, gm/cc	1.59
Rate, meters/second	8100

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-5:

Density, gm/cc	1.64
Charge Wt, lb	0.861

Total No. of Fragments:

For TNT	514
For Subject HE	710

Fragment Velocity: ft/sec

At 9 ft	2800
At 25½ ft	2530
Density, gm/cc	1.61

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White-buff

Principal Uses: HE, SAP, AP projectiles; Shaped Charges

Method of Loading: Pressed

Loading Density: gm/cc

psi x 10^3	
3	12
1.47	1.65

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)

16 hrs at, °C	-54	21
Density, gm/cc	1.51	1.51
Rate, m/sec	7600	7620

Booster Sensitivity Test: (d)

Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	1.70
Density, gm/cc	1.62

Heat of:

Combustion, cal/gm	1210

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. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.

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

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

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

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

0	1	2	3	4	5	6	7	8	9
1380	1451	1492	1493	1424	1325	1556	1687	1338	1639
1910	1761	2112		1614	1585	1936	1787	1388	2179
				1634	1595		1797	1728	
				2154	1715			1838	
					1885				
					2235				

[9] See footnote 1, page 10.

Composition:		
%		
RDX	60	
TNT	40	
Wax, added	1	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		75
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		14
Sample Wt, mg		19
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	3	
Partials	13	
Burned	4	
Unaffected	80	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	526	
1	368	
5 Decomposes	278	
10	255	
15	> 250	
20	> 250	
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
Flammability Index:		177
Hygroscopicity: % 30°C, 90% RH		0.02
Volatility:		

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		
Boiling Point: °C		
Refractive Index, n°_{D}		
n°_{D}		
n°_{D}		
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
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.22*
Lead Azide		0.20*
Tetryl		
* Alternative initiating charges		
Ballistic Mortar, % TNT:	(a)	133
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

Booster Sensitivity Test:		(d)
Condition		Cast
Tetryl, gm		100
Wax, in. for 50% Detonation		1.40
Wax, gm		
Density, gm/cc		1.69

Heat of:		(e)
Combustion, cal/gm		2790
Explosion, cal/gm		1240
Gas Volume, cc/gm		
Formation, cal/gm		
Fusion, cal/gm	(1)	8.0

Specific Heat: cal/gm/°C (1)

°C		°C	
-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/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²	(b)	1610-2580
Density, gm/cc		1.68

Vapor Pressure:
°C mm Mercury

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

	Trials	% Inert
1	4	100
1¼	6	50
1½	2	0
1¾	0	

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

500-lb General Purpose Bomb vs Concrete:

	No Seal	Seal
Height, ft	4000	4000
Trials	65	39
Unaffected	58	36
Low Order	2	2
High Order	5	1

1000-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.65
Charge Wt, lb	2.187
Total No. of Fragments:	
For TNT	703
For Subject HE	998

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.67
Charge Wt, lb	0.882
Total No. of Fragments:	
For TNT	514
For Subject HE	701

Fragment Velocity: ft/sec

At 9 ft	2940
At 25½ ft	2680
Density, gm/cc	1.68

Blast (Relative to TNT): (f)

Air:	
Peak Pressure	110
Impulse	110
Energy	116
Air, Confined:	
Impulse	75
Under Water:	
Peak Pressure	110
Impulse	108
Energy	121
Underground:	
Peak Pressure	104
Impulse	97
Energy	
Crater radius cubed	107

Shaped Charge Effectiveness, TNT = 100:

	(g) Glass Cones	(h) Steel Cones
Hole Volume	178	162
Hole Depth	125	148

Color: Yellow-brown

Principal Uses: Fragmentation bombs, HE projectiles, grenades, shaped charges

Method of Loading: Cast

Loading Density: gm/cc 1.68

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Very slight when stored at 71°C

Origin:

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.

Effect of Temperature on Rate of Detonation: (i)

16 hrs at, °C	-54	24
Density, gm/cc	1.69	1.69
Rate, m/sec	7720	7660

Bulk Modulus at Room Temperature (25°-30°C): (j)

% Wax in Comp B	1	2	3
Dynes/cm² 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

Composition B

Compatibility 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 ($Na_2S \cdot 9H_2O$) 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 Tetryl 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.

[10] See footnote 1, page 10.

(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 Compositiou B:

0	1	2	3	4	5	6	7	8	9
1360	1211	1402	1313	1224	1325	1466	1207	1338	1339
1530	1451	1482	1433	1424	1435	1476	1437	1388	1379
2100	2131	1592	1803	1944	1585	1556	1457	1438	1469
2160	2151		1983	2004	1595	1756	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:	I*	II**
%		
RDX	60	55.2
TNT	40	40.0
Wax, added, (Stanolind or Aristowax, 165°/170°F)	5	
Vinylseal (MA28-14), added	2	
Vistanex (B120)		1.2
Albacer Wax		3.6
C/H Ratio		

Impact Sensitivity, 2 Kg Wt:	I*	II**
Bureau of Mines Apparatus, cm	95	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	14	13
Sample Wt, mg	17	16

Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials %	I*	II**
Explosions	0	0
Partials	0	0
Burned	5	0
Unaffected	95	100

Explosion Temperature: °C		I*	II**
Seconds, 0.1 (no cap used)			
1			
5	Decomposes	260	270
10			
15			
20			

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:	I*	II**
% Loss, 1st 48 Hrs	0.05	0.12
% Loss, 2nd 48 Hrs	0.19	0.18
Explosion in 100 Hrs	None	None

Flammability Index:

Hygroscopicity: %	I*	II**
30°C, 90% RH	0.00	0.00

Volatility:	Nil	Nil

Molecular Weight:	I*	II**
	See Cyclonite	See Comp B

Oxygen Balance:	I*	II**
CO_2 %	See Cyclonite	See Comp B
CO %	See Cyclonite	See Comp B

Density: gm/cc	Cast	1.65	1.65

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n°_{D}

n°_{D}

n°_{D}

Vacuum Stability Test:	I*	II**
cc/40 Hrs, at		
90°C		
100°C		
120°C	0.99	0.92
135°C		
150°C	11+	11+

200 Gram Bomb Sand Test:	I*	II**
Sand, gm	52.7	55.0

Sensitivity to Initiation:	I*	II**
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide	0.22	0.26
Tetryl		

Ballistic Mortar, % TNT:

Trauzl 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

*Desensitized Comp B, designated I, uses emulsified wax.
**Desensitized Comp B, designated II, uses coated RDX.

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:

	I*	II**
Density, gm/cc	1.65	1.65
Charge Wt, lb	0.87	0.86

Total No. of Fragments:

	I*	II**
For TNT	514	514
For Subject HE	609	659

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

*Desensitized Comp B, designated I, uses emulsified wax.
**Desensitized Comp B, designated II, uses coated RDX.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Yellow-brown

Principal Uses: Bombs

Method of Loading: Cast

Loading 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
2[illegible]1	1313	1435	1756
	2053	1865	

Composition C

Composition:

%	
RDX	88.3
Plasticizer, non-explosive	11.7*

*Nonexplosive oily plasticizer containing 0.6% lecithin.

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
Sample Wt, mg	

Friction Pendulum Test:

Steel Shoe

Fiber Shoe

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	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

Molecular Weight:

Oxygen Balance:
CO_2 %
CO %

Density: gm/cc

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n^{20}_D

n^{25}_D

n^{30}_D

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	0.3
120°C	0.7
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 46.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.25
Tetryl	0.11

Ballistic Mortar, % TNT: (a) 120

Trauzl 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

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-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:

	(f) Glass Cones	(g) Steel Cones
Hole Volume	113	114
Hole Depth	101	114

Color: White

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.49

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes above 40°C

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

Composition: %		
RDX	78.7	
TNT	5.0	
DNT	12.0	
MNT	2.7	
NC	0.6	
Solvent	1.0	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		90
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		
Sample Wt, mg		
Friction Pendulum Test:		
Steel Shoe		
Fiber Shoe		
Rifle Bullet Impact Test:	Trials %	
Explosions	0	
Partials	20	
Burned	0	
Unaffected	80	
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		1.8
% Loss, 2nd 48 Hrs		1.4
Explosion in 100 Hrs		None
Flammability Index:		178
Hygroscopicity: % 30°C, 95% RH		0.55
Volatility: 25°C, 5 days		0.00

Molecular Weight:		
Oxygen Balance:		
CO_2 %		
CO %		
Density: gm/cc		
Melting Point: °C		
Freezing Point: °C		
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		2.0
120°C		9.0
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		47.5
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.25
Tetryl		0.10
Ballistic Mortar, % TNT:	(a)	126
Trauzl Test, % TNT:		
Plate Dent Test:	(c)	
Method		B
Condition		Hand tamped
Confined		No
Density, gm/cc		1.52
Brisance, % TNT		111
Detonation Rate:	(d)	
Confinement		None
Condition		Hand tamped
Charge Diameter, in.		1.0
Density, gm/cc		1.57
Rate, meters/second		7660

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: White

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.57

Storage:

Method: Dry

Hazard Class (Quantity-Distance): Class 9

Compatibility Group: Group I

Exudation: Volatilizes above 52°C

Plasticity:

Below 0°C	Plastic (-30°C)
0-40°C	Plastic
above 40°C	Hard (52°C)*

*Due to volitalization of plasticizer.

References:

See references for Composition C-4.

Composition C-3

Composition:		
%		
RDX		77
Tetryl		3
TNT		4
DNT		10
MNT		5
NC		1
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		100+
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		14
Sample Wt, mg		33
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	0	
Partials	40	
Burned	0	
Unaffected	60	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)		
1		
5	Decomposes	280
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		
100°C Heat Test:		
% Loss, 1st 48 Hrs		3.20
% Loss, 2nd 48 Hrs		1.63
Explosion in 100 Hrs		None
Flammability Index:		
Hygroscopicity: %	30°C, 95% RH	2.4
Volatility:	25°C, 5 days	1.15

Molecular Weight:		
Oxygen Balance:		
CO_2 %		
CO %		
Density: gm/cc		
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n°_{D}		
n°_{D}		
n°_{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		1.21
120°C		11+
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		53.1
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.08
Ballistic Mortar, % TNT:	(a)	126
Trauzl Test, % TNT:	(b)	117
Plate Dent Test:	(c)	
Method		B
Condition		Hand tamped
Confined		No
Density, gm/cc		1.57
Brisance, % TNT		118
Detonation Rate:	(d)	
Confinement		None
Condition		Hand tamped
Charge Diameter, in.		1.0
Density, gm/cc		1.60
Rate, meters/second		7625

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-5:

Density, gm/cc	1.60
Charge Wt, lb	0.842

Total No. of Fragments:

For TNT	514
For Subject HE	671

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

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

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Yellow

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.58

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes at 77°C

Plasticity:

Below 0°C	Hard (-29°C)
0-40°C	Plastic
Above 40°C	Exudes (77°C)

Booster Sensitivity Test: (h)

Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	1.36
Density, gm/cc	1.62

References:

See references for Composition C-4.

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	
		Melting Point: °C	
C/H Ratio		**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^{25}	
Picatinny Arsenal Apparatus, in.	19	n_D^{30}	
Sample Wt, mg	27		
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	0.26
	%	120°C	
Explosions	0	135°C	
Partials	0	150°C	
Burned	20	**200 Gram Bomb Sand Test:**	
Unaffected	80	Sand, gm	55.7
Explosion Temperature:	°C	**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5	290	Lead Azide	0.20
10		Tetryl	0.10
15		**Ballistic Mortar, % TNT:** (a)	130
20		**Trauzl Test, % TNT:**	
75°C International Heat Test:		**Plate Dent Test:** (c)	
% Loss in 48 Hrs		Method	B
100°C Heat Test:		Condition	Hand tamped
% Loss, 1st 48 Hrs	0.13	Confined	No
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	1.60
Explosion in 100 Hrs	None	Brisance, % TNT	115
Flammability Index:		**Detonation Rate:** (d)	
Hygroscopicity: % 30°C, 95% RH	Nil	Confinement	None
Volatility:		Condition	Hand tamped
		Charge Diameter, in.	1.0
		Density, gm/cc	1.59
		Rate, meters/second	8040

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: Light brown

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None at 77°C

Effect of Temperature on Rate of Detonation: (1)

16 hrs at, °C	-54	21
Density, gm/cc	1.36	1.35
Rate, m/sec	7020	7040

Plasticity:

Below 0°C	Plastic (-57°C)
0-40°C	Plastic
Above 40°C	Plastic (77°C)

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

Preparat'on:

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 Co[illegible]ition, 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 Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

[11]See footnote 1, page 10.

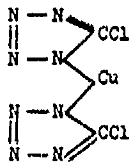
(i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2383, November 1956.

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

	0	1	3	4	5	6	7	8	9
Comp C	1260		1293					1518 1838	
Comp C-2			1293			1416		1518	
Comp C-3		1611	1713	2154	1595 1695 1885	1416 1556 1766	1797	1518 2028	
Comp C-4						1766	1907	1828 1958	1819

Composition:

%	
C	8.9
N	41.5
Cl	26.2
Cu	23.4
C/H Ratio	



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	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	305
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	2.67
% Loss, 2nd 48 Hrs	0.10
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 3.11

Volatility:

Molecular Weight: ($CuC_2N_8Cl_2$) 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}

Vacuum Stability Test:
cc/40 Hrs, at
90°C
100°C
120°C
135°C
130°C

200 Gram Bomb Sand Test: (£)

Sand, gm	27.4	25.3
Black powder fuse		17.0

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate		
Lead Azide	0.20	0.30
Tetryl	0.10	

Ballistic Mortar, % TNT:

Trauzl 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

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-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: Blue

Principal Uses: Primary explosive

Method of Loading: Pressed

Loading Density: gm/cc (c)

psi x 10^3	10	20	40	70
gm/cc	1.49	1.63	1.74	1.86

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M
Exudation	None

Stab Sensitivity: (c)

Density gm/cc	Firing Point (inch-ounces) 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

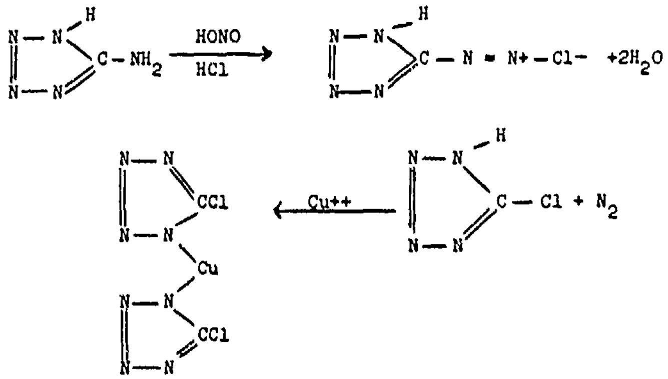
Specific Heat, cal/gm/°C

Temp range 0°-30°C 0.155
Wt of sample, gm 0.8910

Copper Chlorotetrazole

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. Stollé (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.

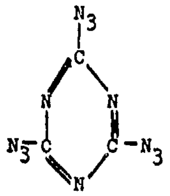
(c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimum Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Compounds, PATR No. 2146, February 1955.

[12]See footnote 1, page 10.

Cyanuric Triazide

Composition:

	%
C	17.6
N	82.4



C/H Ratio

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	-

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)	252
1	
5	
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

Flammability Index:

Hygroscopicity: %

Volatility: Decomposes above 100°C

Molecular Weight: (C_3N_{12}) 204

Oxygen Balance:

CO_2 %	-47.1
CO %	-23.5

Density: gm/cc Crystal 1.54

Melting Point: °C 94

Freezing Point: °C

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

120°C

135°C

150°C

200 Gram Bomb Sand Test:

Sand, gm 32.2

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	-
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement	-
Condition	-
Charge Diameter, in.	0.3
Density, gm/cc	1.15
Rate, meters/second	5550-5600

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: Colorless

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

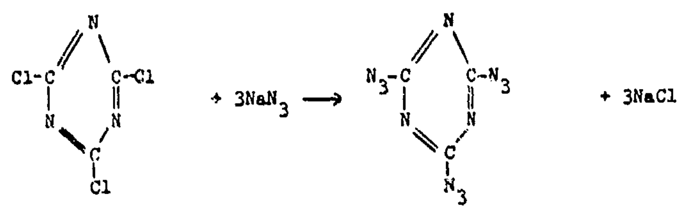
Storage:

Method	
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	— —
Exudation	None

Cyanuric Triazide

Preparation:

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).

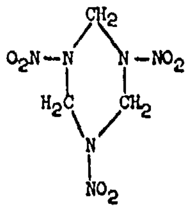
Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

[13] See footnote 1, page 10.

Cyclonite* (RDX)

Composition:

%	
C	16.3
H	2.7
N	37.8
O	43.2



C/H Ratio 0.095

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	
Partials	0	
Burned	0	
Unaffected	0	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	405	
1	316	
5 Decomposes	260	
10	240	
15	235	
20	-	
75°C International Heat Test:		
% Loss in 48 Hrs		0.03
100°C Heat Test:		
% Loss, 1st 48 Hrs		0.04
% Loss, 2nd 48 Hrs		0.00
Explosion in 100 Hrs		None
Flammability Index:	(d)	278
Hygroscopicity: % 25°C, 100% RH		0.02
Volatility:		Nil

Molecular Weight:	($C_3H_6N_6O_6$)	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^{D}_{20}		
n^{D}_{25}		
n^{D}_{30}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		0.7
120°C		0.9
135°C		-
150°C		2.5
200 Gram Bomb Sand Test:		
Sand, gm		60.2
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.19*
Lead Azide		0.05*
Tetryl		-
* Alternative initiating charges.		
Ballistic Mortar, % TNT:	(a)	150
Trauzl Test, % TNT:	(b)	157
Plate Dent Test:	(c)	
Method		A
Condition		Pressed
Confined		Yes
Density, gm/cc		1.50
Brisance, % TNT		135
Detonation Rate:		
Confinement		None
Condition		Pressed
Charge Diameter, in.		1.0
Density, gm/cc		1.65
Rate, meters/second		8180

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

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

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

Specific Heat: cal/gm/°C

°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: (h)

cal/sec/cm/°C	1.263	6.91×10^{-4}
Density, gm/cc	1.533	6.98×10^{-4}

Coefficient of Expansion:
Linear, %/°C

Volume, %/°C

Hardness, Mohs' Scale: 2.5

Young's Modulus:
E', dynes/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure:
°C mm Mercury

Decomposition Equation: (i)

Oxygen, atoms/sec (Z/sec)	$10^{18.5}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	47.5
Temperature Range, °C	213-299
Phase	Liquid

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

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

Cyclonite (RDX)

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: White

Principal Uses: Detonator base charge, and ingredient for projectile and bomb fillers

Method of Loading: Pressed

Loading Density: gm/cc psi x 10^3

3	5	10	12	15	20
1.46	1.52	1.60	1.63	1.65	1.68

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M (wet) Group L (dry)
Exudation	None

Effect of Temperature on Rate of Detonation: (k)

16 hrs at, °C	-54	21
Density, gm/cc	1.61	1.62
Rate, m/sec	8100	8050

Effect of Temperature on Impact Sensitivity:

Temp. °C	PA Impact Test 2Kg Wt, inches
Room	9
32.2	8
104	5

Cyclonite (RDX)

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

Water

°C	%
30	0.005
50	0.025
70	0.076
90	0.19
100	0.28

Alcohol

°C	%
0	0.040
20	0.105
40	0.240
60	0.579
78	1.195

Acetone

°C	%
0	4.4
20	7.3
40	11.5
60	18.

Benzene

°C	%
20	0.05
40	0.09
60	0.20
80	0.41

Toluene

°C	%
0	0.015
20	0.02
40	0.05
60	0.13
80	0.30
100	0.65

Ethyl acetate

°C	%
28	2.9
94	18.

Carbon tetrachloride

°C	%
50	0.005
60	0.007
70	0.009

Methanol

°C	%
0	0.14
20	0.23
40	0.47
60	1.1

Ether

°C	%
10	0.05
20	0.056
30	0.076

TNT

°C	%
80	4.4
85	5.0
90	5.55
95	6.2
100	7.0
105	7.9

Isoamyl alcohol

°C	%
0	0.02
20	0.03
40	0.065
60	0.22
80	0.54
100	1.35

Methyl acetate

°C	%
20	2.9
30	3.3
40	4.1
50	5.6

β-Ethoxyethyl acetate

°C	%
20	0.15
30	0.16
40	0.19
50	0.25

Chlorobenzene

°C	%
20	0.33
30	0.44
40	0.56
50	0.74

Trichloroethylene

°C	%
20	0.20
30	0.22
40	0.24
50	0.26

Tetrachloroethane

°C	%
38	0.09

Isopropanol

°C	%
38	0.18

Isobutanol

°C	%
20	0.0

Chloroform

°C	%
20	0.01

Mesityloxide

°C	%
27	3.2
97	12.2

Cyclohexanone

°C	%
25	12.7
97	25

Nitrobenzene

°C	%
25	1.5
97	12.4

Nitroethane

°C	%
28	3.6
93	19

Cyclopentanone

°C	%
28	11.5
90	37

Acetonitrile

°C	%
28	11
82	33

Methyl ethyl ketone

°C	%
28	5.6
95	14

Cyclonite (RDX)

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

Solvent	Boiling Point, °C	Grade or Source*	Solubility gm/100 gm Solvent 28°C	Solubility gm/100 gm Solvent Heated	Crystalline Form
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	114.0	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.[illegible] 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

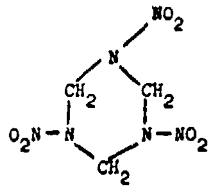
* EK, Eastman Kodak; Pract, practical.

Cyclonite (RDX)

Preparation:

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

$$(CH_2)_6N_4 + 4HNO_3 + 2NH_4NO_3 + 6(CH_3CO)_2O$$



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

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

Origin:

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

Destruction by Chemical Decomposition:

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

References:[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.

[14] See footnote 1, page 10.

(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 2861, 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, PATR No. 2393, November 1956.

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

0	1	2	3	4	5	6	7	8	9
1170	1211	582	863	1184	65	1236	857	1438	709
1290	1241	1342	1193	1414	1175	1316	1207	1458	1379
1360	1311	1352	1293	1454	1185	1416	1427	1498	1429
1450	1421	1372	1433	1614	1435	1446	1437	1578	1449
1760	1481	1402	1483	1634	1445	1466	1517	1838	1469
1930	1561	1452	1503	2024	1715	1476	1617	1958	1709
2100	1611	1492	1693	2154	1855	1516	1687	1958	1909
	1651	1532	1713	2204	1885	1556	1737	2008	2059
	1741	2062	1793		1915	1756	1747	2028	2179
	1751	2112	1923		1935	1766	1787	2178	
	1761				2095	1796	1797	2198	
	2131				2125	1836	1957		
	2151				2205	1936	2147		
						1956	2227		
						2016			
						2056			
						2176			

Cyclotol, 75/25

Composition:	
%	
RDX	75
TNT	25
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
Sample Wt, mg	
Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
Rifle Bullet Impact Test:	Trials
	%
Explosions	30
Partials / Smokes	40
Burned	0
Unaffected	30
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	
1	
5	
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	
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:		224
Oxygen Balance:		
CO_2 %		-35
CO %		- 6
Density: gm/cc	Cast	1.71
Melting Point: °C		
Freezing Point: °C		
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		0.23
120°C		0.41
135°C		-
150°C		-
200 Gram Bomb Sand Test:		
Sand, gm		
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:		
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
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

Cyclotol, 75/25

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

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.

Specific Heat: cal/gm/°C (h)

°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

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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-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): (d)

Air:

Peak Pressure	111
Impulse	126
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-buff

Principal Uses: Shaped charge bomb especially fragmentation; HE projectiles; grenades

Method of Loading: Cast

Loading Density: gm/cc 1.71

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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):

Dynes/cm^2 x 10^{-10}	3.09
Density, gm/cc	1.74

Absolute Viscosity, poises:*

Temp, 85°C	210**
90°C	--

Efflux Viscosity, Saybolt Seconds:

Temp, 85°C	9-14

* Compositions using Spec Grade Type A, Class A RDX.

** Composition prepared using RDX of optimum particle size.

Composition:	%	
RDX	70	
TNT	30	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	60	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	14	
Sample Wt, mg	20	
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	30	
Partials	30	
Burned	0	
Unaffected	40	
Explosion Temperature:		°C
Seconds, 0.1 (no cap used)		-
1		-
5	Decomposes	265
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs		
100°C Heat Test:		
% Loss, 1st 48 Hrs	0.07	
% Loss, 2nd 48 Hrs	0.08	
Explosion in 100 Hrs	None	
Flammability Index:		
Hygroscopicity: %	Nil	
Volatility:	Nil	

Molecular Weight:		224
Oxygen Balance:		
CO_2 %		-37
CO %		- 8
Density: gm/cc	Cast	1.71
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		0.86
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		56.6
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.21*
Lead Azide		0.20*
Tetryl		
*Alternative initiating charges.		
Ballistic Mortar, % TNT:	(a)	135
Trauzl Test, % TNT:		
Plate Dent Test:	(b)	
Method		B
Condition		Cast
Confined		No
Density, gm/cc		1.725
Brisance, % TNT		136
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.73
Rate, meters/second		8060

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, M42A1 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

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

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	

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones (e)
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

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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.

Composition: %		**Molecular Weight:**	224
RDX	65	**Oxygen Balance:**	
TNT	35	CO_2 %	-40
		CO %	- 9
		Density: gm/cc Cast	1.71
		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_{20}^{D}	
Sample Wt 20 mg		n_{25}^{D}	
Picatinny Arsenal Apparatus, in.		n_{30}^{D}	
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: Trials		100°C	
%		120°C	
Explosions		135°C	
Partials		150°C	
Burned		**200 Gram Bomb Sand Test:**	
Unaffected		Sand, gm	55.4
Explosion Temperature: °C		**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Decomposes	270	Lead Azide	
10		Tetryl	
15		**Ballistic Mortar, % TNT:** (a)	134
20		**Trauzl Test, % TNT:**	
75°C International Heat Test:		**Plate Dent Test:**	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
Flammability Index:		**Detonation Rate:**	
		Confinement	None
Hygroscopicity: %	Nil	Condition	Cast
		Charge Diameter, in.	1.0
Volatility:	Nil	Density, gm, cc	1.72
		Rate, meters/second	7975

Cyclotol, 65/35

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.71
Charge Wt, lb	2.253
Total No. of Fragments:	
For TNT	703
For Subject HE	1153

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.71
Charge Wt, lb	0.922
Total No. of Fragments:	
For TNT	514
For Subject HE	769

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

Heat of: *

Combustion, cal/gm	2755
Explosion, cal/gm	1205
Gas Volume, cc/gm	845

* Calculated from composition of mixture.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones (e)
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

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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.

Eutectic Temperature, °C: 79

gm RDX/100 gm TNT

79°C	4.16
95°C	5.85

Absolute Viscosity, poises:*

Temp, 85°C	30.2
90°C	26.0

* Composition using Spec Grade Type A, Class A RDX.

Composition:		
%		
RDX	60	
TNT	40	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	75	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	14	
Sample Wt, mg	19	
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	5	
Partials	55	
Burned	25	
Unaffected	15	
Explosion Temperature:		°C
Seconds, 0.1 (no cap used)		
1		
5	Decomposes	280
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		
Flammability Index:		
Hygroscopicity: %	Nil	
Volatility:	Nil	

Molecular Weight:		224
Oxygen Balance:		
CO_2 %		-43
CO %		10
Density: gm/cc	Cast	1.68
Melting Point: °C		
Freezing Point: °C		
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		
120°C		0.29
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		54.6
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.22*
Lead Azide		0.20*
Tetryl		
*Alternative initiating charges.		
Ballistic Mortar, % TNT:	(a)	1.33
Trauzl Test, % TNT:		
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

Cyclotol, 60/40

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.65
Charge Wt, lb	2.187

Total No. of Fragments:

For TNT	703
For Subject HE	998

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.67
Charge Wt, lb	0.882

Total No. of Fragments:

For TNT	514
For Subject HE	701

Fragment Velocity: ft/sec (c)

At 9 ft	2965
At 25½ ft	2800
Density, gm/cc	--

Blast (Relative to TNT): (d)

Air:

Peak Pressure	104
Impulse	116
Energy	--

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Heat of: *

Combustion, cal/gm	2820
Explosion, cal/gm	1195
Gas Volume, cc/gm	845

Compressive Strength: lb/inch^2

1.70 gm/cc	2200-3000

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones	(e)
Hole Volume	178	162	
Hole Depth	125	148	

Color: Yellow-buff

Principal Uses: Shaped charge bomb; especially fragmentation HE projectiles, grenades

Method of Loading: Cast

Loading Density: gm/cc 1.68

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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.

Bulk Modulus at Room Temperature (25°-30°C):

Dynes/cm^2 x 10^{-10}	4.14
Density, gm/cc	1.72

Absolute Viscosity, poises:*

Temp, 85°C	12.3
90°C	--

* Compositions using Spec Grade Type A, Class A RDX.

* Calculated from composition of mixture.

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:

0	1	2	3	4	5	6	7	8	9
1290	1651	1482	1483	1824	1435	1476	1427	1398	1469
1530	1741		1793	1834	1585	1756	1507	1488	1509
			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.

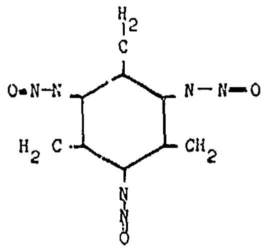
[15]See footnote 1, page 10.

Cyclotrimethylene Trinitrosamine

Composition:

	%
C	20.6
H	3.5
N	48.3
O	27.6

C/H Ratio 0.12



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15 to 22
Sample Wt, mg	17 to 20

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	220
10	
15	
20	

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:

Hygroscopicity: % 30°C, 90% RH 0.02

Volatility:

Molecular Weight: ($C_3H_6N_6O_3$) 174

Oxygen Balance:

CO_2 %	-55
CO %	-28

Density: gm/cc

Melting Point: °C 105 to 107

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_D^{20}
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.

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

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate: (b)

Confinement	None
Condition	Cast
Charge Diameter, in.	1.2
Density, gm/cc	1.42
Rate, meters/second	7000 to 7300

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

Principal Uses: Ingredient of projectile filler

Method of Loading: Pressed or cast with added melting point depressants

Loading Density: gm/cc See below

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M
Exudation	None

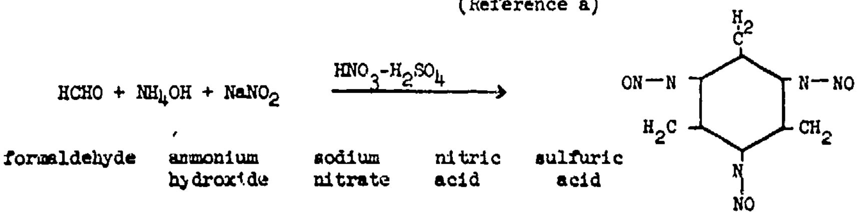
Density at Various Pressures: (b)

lb/inch^2	gm/cc
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

Heat of:

Combustion, cal/gm	3158
Explosion, cal/gm	876
Formation, cal/gm	-914

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 isoamyl 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.

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 Practique" 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)

42% Cyclotrimethylene Trinitrosamine
58% TNT

Rate of Detonation, meters/second

7,000

Reaction 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 Proprietés 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.

[16]See footnote 1, page 10.

DBX (Depth Bomb Explosive)

Composition:	%	
Ammonium Nitrate	21	
RDX	21	
TNT	40	
Aluminum	18	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	35	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	13	
Sample Wt, mg	14	
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	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		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Molecular Weight:		83
Oxygen Balance:		
CO_2 %		-46
CO %		-26
Density: gm/cc	Cast	1.68
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
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
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.10
Ballistic Mortar, % TNT:	(a)	146
Trauzl Test, % TNT:		
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

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

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):	(d)
Air:	
Peak Pressure	118
Impulse	127
Energy	138
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	--
Impulse	--
Energy	136
Underground:	
Peak Pressure	
Impulse	
Energy	

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:	Gray
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.

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.

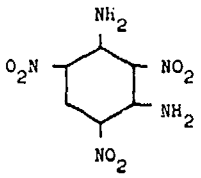
(e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

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

[17]See footnote 1, page 10.

Composition:

%	
C	29.6
H	2.1
N	28.8
O	39.5
C/H Ratio	0.380



Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	18
Sample Wt, mg	9
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	
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.4
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight: ($C_6H_5N_5O_6$)		243
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_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		46.6
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		----
Lead Azide		0.20
Tetryl		0.10
Ballistic Mortar, % TNT:		100
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Pressed
Charge Diameter, in.		0.5
Density, gm/cc		1.65
Rate, meters/second		7500

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Yellow
For TNT	**Principal Uses:**
For Subject HE	
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Pressed
For TNT	
For Subject HE	
Fragment Velocity: ft/sec	**Loading Density:** gm/cc
At 9 ft	At 50,000 psi 1.65
At 25½ ft	
Density, gm/cc	
Blast (Relative to TNT):	**Storage:**
Air:	Method Dry
Peak Pressure	Hazard Class (Quantity-Distance)
Impulse	Compatibility Group
Energy	Exudation None
Air, Confined:	Cook-Off Temperature: °C 320
Impulse	Time, minutes 8
Under Water:	Heat of:
Peak Pressure	Explosion, cal/gm 2876
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	

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

Preparation:

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

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

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (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. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATNB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene hydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH_3 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 Schepers (Akad Amsterdam Versl 22, 297).

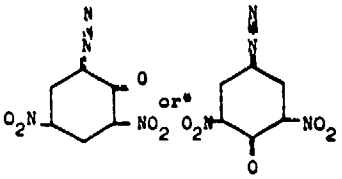
C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennep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

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

A recent report describes the preparation of DATNB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with H_2SO_4-HNO_3 acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to 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.

Composition:

%	
C	34.3
H	0.9
N	26.7
O	38.1



C/H Ratio 1.056

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

Friction Pendulum Test:

Steel Shoe	Detonates
Fiber Shoe	Detonates

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	200
5	195
10	180
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	2.10
% Loss, 2nd 48 Hrs	2.20
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.04

Volatility: 50°C, 30 months Unaffected

Molecular Weight: ($C_6H_2N_4O_5$) 210

Oxygen Balance:

CO_2 %	-61
CO %	-15

Density: gm/cc Crystal 1.63

Melting Point: °C 157

Freezing Point: °C

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	7.6
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm	47.5
Black powder fuse	45.6

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT: (a) 97

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement			
Condition		Pressed	
Charge Diameter, in.			
Density, gm/cc	0.9	1.5	1.6
Rate, meters/second	4400	6600	6900

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

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 needles

Principal Uses: Percussion caps

Method of Loading: Pressed

Loading Density: gm/cc

Apparent	0.27
At 3000 psi	1.14

Storage:

Method	Under water
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

Solubility:

Soluble in nitroglycerin, nitrobenzene, aniline, pyridine, concentrated hydrochloric acid, and in most common organic solvents.

Heat of:

Combustion, cal/gm	3243
Explosion, cal/gm	820
Gas Volume, cc/gm	865

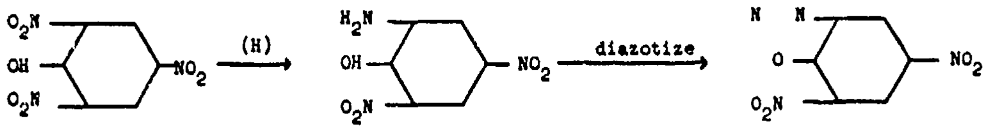
Sensitivity to Electrostatic Discharge, Joules: (b) 0.012

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

Solubility at 50°C

Solvent	%
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

[18]See footnote 1, page 10.

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

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

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

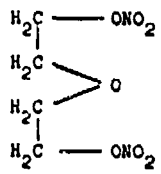
(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

0	2	4	5	7	8	9
150	1352	34	355	827	318	2179
610		214			1838	
2120						

Diethylene Glycol Dinitrate (DEGN) Liquid

Composition:

%	
C	24.5
H	4.1
N	14.3
O	57.1



C/H Ratio 0.143

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	9
Sample Wt, mg	

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber Shoe	

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	237
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	4.0
% Loss, 2nd 48 Hrs	3.0
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility: 60°C, $mg/cm^2/hr$ 193

Molecular Weight: ($C_4H_8N_2O_7$) 196

Oxygen Balance:

CO_2 %	-41
CO %	-8

Density: gm/cc Liquid 1.38

Melting Point: °C 2

Freezing Point: °C

Boiling Point: °C Decomposes 160

Refractive Index,

n_D^{20}	
n_D^{25}	1.4498
n_D^{30}	

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	0.3cc/20 hr/gm
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 42.2

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT: 90

Trauzl Test, % TNT: 77

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.38
Rate, meters/second	6760

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:

Combustion, cal/gm	2792
Explosion, cal/gm	841
Gas Volume, cc/gm	796
Formation, cal/gm	2020
Fusion, cal/gm	

Specific Heat: cal/gm/°C

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

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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

Viscosity, centipoises:

Temp, 20°C	8.1

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Colorless

Principal Uses: Propellant compositions

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Liquid
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Preparation: DEGN can be prepared with approximately 85% yield by adding diethyleneglycol to mixed acid (50% HNO_3, 45% H_2SO_4, and 5% H_2O). 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.

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	∞
Alcohol	∞
2:1 Ether:Alcohol	∞
Acetone	∞

Diethylene Glycol Dinitrate (DEGN) Liquid

Origin:

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

Destruction by Chemical Decomposition:

DEGN is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide ($Na_2S \cdot 9H_2O$). 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:

0	1	2	3	4	6	7	9
50	231	72	673	494	346	487	279
180	551	602	1443	1624	1516	1427	579
620	1391	1282			1616	1487	1439
1490	1421	1392			1786	1817	
1990							

[19] See footnote 1, page 10.

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

Composition: %	
C 31.6	$CHCO_2CH_2C(NO_2)_2CH_3$
H 3.2	|
N 14.7	$CHCO_2CH_2C(NO_2)_2CH_3$
O 50.5	
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	18
Sample Wt, mg	18

Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test:	Trials
	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature:		°C
Seconds, 0.1 (no cap used)		---
1		---
5	Smokes	250
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

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: ($C_{10}H_{12}N_4O_{12}$)	380

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

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	0.66
120°C	----
135°C	0.91
150°C	

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:	
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.49
Rate, meters/second	6050

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

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** White
For TNT	
For Subject HE	**Principal Uses:**
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Cast
For TNT	
For Subject HE	**Loading Density:** gm/cc 1.50
Fragment Velocity: ft/sec	**Storage:**
At 9 ft	Method: Dry
At 25½ ft	Hazard Class (Quantity-Distance)
Density, gm/cc	Compatibility Group
Blast (Relative to TNT):	Exudation: None
Air:	**Heat of:**
Peak Pressure	Combustion, cal/gm: 3070 (calculated)
Impulse	Detonation, cal/gm: 767 (calculated)
Energy	**Viscosity, poises:**
Air, Confined:	Temp, 98.9°C: 0.586
Impulse	106.5°C: 0.435
Under Water:	**Liquid Density, gm/cc:**
Peak Pressure	Temp, 98.9°C: 1.382
Impulse	106.5°C: 1.375
Energy	**Origin:**
Underground:	Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.
Peak Pressure	
Impulse	
Energy	

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

Preparation: (a, b)

$$\begin{matrix} HC\text{-}COCl \\ \| \\ HC\text{-}COCl \end{matrix} + 2CH_3C(NO_2)_2CH_2OH \xrightarrow{AlCl_3} \begin{matrix} HC\text{-}CO_2CH_2C(NO_2)_2CH_3 \\ \| \\ HC\text{-}CO_2CH_2C(NO_2)_2CH_3 \end{matrix}$$

3.3 mol fumaryl chloride	7.3 mol 2,2-dinitropropanol	1.6 mol aluminum chloride	83% yield bis(dinitropropyl) fumarate

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.

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

Composition:	
%	
C 31.4	
H 3.7	$CH_2CO_2CH_2C(NO_2)_2CH_3$
N 14.7	|
O 50.2	$CH_2CO_2CH_2C(NO_2)_2CH_3$
C/H Ratio 0.250	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
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	>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	
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:	$(C_{10}H_{14}N_4O_{12})$	382
Oxygen Balance:		
CO_2 %		-63
CO %		-21
Density: gm/cc	Crystal	1.51
Melting Point: °C		86
Freezing Point: °C		
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		0.10
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:		
Trauzl 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		

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: White

Principal Uses:

Method of Loading: Cast

Loading Density: gm/cc

Storage:

Method	Dry
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.

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

Preparation: (a)

$$2CH_3C(NO_2)_2CH_2OH + \begin{array}{l} CH_2COCl \\ CH_2COCl \end{array} \xrightarrow{AlCl_3} \begin{array}{l} CH_2COOCH_2C(NO_2)_2CH_3 \\ CH_2COOCH_2C(NO_2)_2CH_3 \end{array} + 2HCl$$

dinitropropanol; succinyl chloride; aluminum chloride; bis(2,2-dinitropropyl) succinate

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).

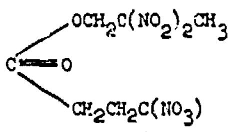
References:[21]

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

[21]See footnote 1, page 10.

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

Composition: %	**Molecular Weight:** ($C_7H_9N_5O_{12}$) 355
C 23.6	**Oxygen Balance:**
H 2.5	CO_2 % -29
N 19.7	CO % +2.3
O 54.2	**Density:** gm/cc Crystal 1.68
C/H Ratio	**Melting Point:** °C Form I 11, Form II 95, Form III 59
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	**Boiling Point:** °C
Bureau of Mines Apparatus, cm	**Refractive Index,** n^{o}_{D}
Sample Wt 20 mg	n^{o}_{D}
Picatinny Arsenal Apparatus, in.	n^{o}_{D}
Sample Wt, mg	
Friction Pendulum Test:	**Vacuum Stability Test:**
Steel Shoe	cc/40 Hrs, at
Fiber Shoe	90°C ---
Rifle Bullet Impact Test: Trials %	100°C 0.5
Explosions	120°C
Partials	135°C
Burned	150°C
Unaffected	**200 Gram Bomb Sand Test:**
	Sand, gm
Explosion Temperature: °C	**Sensitivity to Initiation:**
Seconds, 0.1 (no cap used) ---	Minimum Detonating Charge, gm
1 ---	Mercury Fulminate
5 300	Lead Azide
10	Tetryl
15	**Ballistic Mortar, % TNT:**
20	**Trauzl Test, % TNT:**
75°C International Heat Test:	**Plate Dent Test:**
% Loss in 48 Hrs	Method
100°C Heat Test:	Condition
% Loss, 1st 48 Hrs	Confined
% Loss, 2nd 48 Hrs	Density, gm/cc
Explosion in 100 Hrs	Brisance, % TNT
Flammability Index:	**Detonation Rate:**
Hygroscopicity: %	Confinement
Volatility:	Condition
	Charge Diameter, in.
	Density, gm/cc 1.67
	Rate, meters/second 7600



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-5:
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses:

Method of Loading: Cast

Loading Density: gm/cc 1.67

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	None

Heat of: (c)

Transition, cal/gm	Solvent CCl_4	Solvent DMF
I → III	6.2	4.8
II → I	-16.6	-22.0

Heat of Solution, 30°C:

Material	ΔH Solution, cal/gm CCl_4	ΔH Solution, cal/gm DMF
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)

Preparation: (a, b)

$$CH_3C(NO_2)_2OH + (NO_2)_3CCH_2CH_2COCl \xrightarrow{AlCl_3} CH_3C(NO_2)_2CH_2COOCH_2C(NO_2)_3 + HCl$$

dinitropropanol + trinitrobutyryl chloride, with aluminum chloride → dinitropropyl trinitrobutyrate

Dinitropropanol, trinitrobutyryl chloride and aluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture w 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.

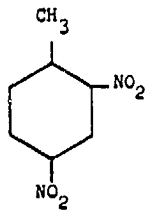
(c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, NAVORD Report No. 4427, 11 December 1956.

[22] See footnote 1, page 10.

2,4-Dinitrotoluene (DNT)

Composition:

%	
C	46.3
H	3.3
N	15.4
O	35.0



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

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	0
Burned	0
Unaffected	100

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	°C
1	
5 Decomposes	310
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

Flammability Index:

Hygroscopicity: % 25°C, 100% RH 0.00

Volatility:

Molecular Weight: ($C_7H_6N_2O_4$) 182

Oxygen Balance:

CO_2 %	-114
CO %	- 53

Density: gm/cc 1.521

Melting Point: °C 71

Freezing Point: °C

Boiling Point: °C Decomposes 300

Refractive Index, n_{20}^{D}
n_{25}^{D}
n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	
120°C	0.04
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 19.3

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.25

Ballistic Mortar, % TNT: (a) 71

Trauzl Test, % TNT: (b) 64

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

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

Principal Uses: Ingredient of propellant powder, dynamites and plastic explosives

Method of Loading: Pressed, extruded or cast composition

Loading Density: gm/cc Variable

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 12
Compatibility Group	Group D
Exudation	

65.5°C KI Test:

Minutes 60+

Heat of:

Combustion, cal/gm (b) 1545

Thermal Conductivity:

cal/sec/cm/°C
Density 1.322 gm/cc 6.28×10^{-4}

2,4-Dinitrotoluene (DNT)

Preparation:

See TNT.

Solubility: gm/100 gm of the following substances:

30% Ethyl Alcohol		Nitroglycerin		Water	
°C	%	°C	%	°C	%
25	0.16	20	30	22	0.027
35	0.29			50	0.037
45	0.49			100	0.254
55	0.77				
60	1.03				

Solubility at 15°C, in:

Solvent	%	Solvent	%
$CHCl_3$	65.076	C_2H_5OH (absolute)	3.039
CCl_4	2.431	Ether (absolute)	9.422
C_6H_6	60.644	Acetone	81.901
Toluol	45.470	Ethyl acetate	57.929
CH_3OH	5.014	CS_2	2.306
C_2H_5OH (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.

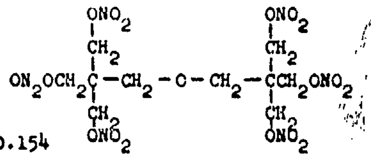
(d) Also see the following Picatinny Arsenal Technical Reports on DNT:

0	1	2	3	4	5	6	7	8	9
810	1351	72	43	394	1615	186	97	768	69
1830	1501	372	233	804	2125	1556	817	938	149
	1651	[illegible]	343	1044		1816	837	1538	249
	1781	[illegible]	673	1084		1896			279
	1821	1672	1023	1094					779
	2031	1692	1663	1164					1749
	2221		1743	1324					
			2013	1464					
				1524					
				1674					
				1754					
				2094					

[23] See footnote 1, page 10.

Composition:

%	
C	21.7
H	2.9
N	15.2
O	60.2



C/H Ratio 0.154

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	14
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	4
Sample Wt, mg	10

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		
1		300
5	Explodes	255
10		
15		
20		

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.11
% Loss, 2nd 48 Hrs	0.10
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 0.03

Volatility:

Molecular Weight: ($C_{10}H_{16}N_6O_{19}$) 554

Oxygen Balance:

CO_2 %	-26
CO %	+ 3

Density: gm/cc Crystal 1.63

Melting Point: °C 73.7

Freezing Point: °C

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	3.7
120°C	11+
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 57.4

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT: (a) 142

Trauzl Test, % TNT: (b) 128

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate: (c)

Confinement	Copper tube
Condition	Pressed
Charge Diameter, in.	0.39
Density, gm/cc	1.59
Rate, meters/second	7410

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 :
Density, gm/cc
Charge Wt, lb

Total No. of Fragments:
For TNT
For Subject HE

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses: Ingredient of priming compositions

Method of Loading: Pressed

Loading Density: gm/cc
At 3000 to 4000 psi 1.59

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Preparation: (Chemistry of Powder and Explosives, Davis)

$$2(HO\text{-}CH_2)_4C \xrightarrow{\text{Dehydration}} (HO\text{-}CH_2)_3C\text{-}O\text{-}C(CH_2\text{-}OH)_3 \longrightarrow (O_2NO\text{-}CH_2)_3C\text{-}O\text{-}C(CH_2\text{-}ONO_2)_3$$

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

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, Leipsiz, p. 363.

(c) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-283.

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

[24]See footnote 1, page 10.

Dynamite, Low Velocity, Picatinny Arsenal (LVD)

Composition: %	
99.5/0.5 RDX/1-MA dye*	17.5
TNT	67.8
Tripentaerythritol	8.6
68/32 Vistac No 1/DOS binders**	4.1
Cellulose acetate, LH-1	2.0
*RDX, Class E; 1-MA is 96% pure 1-methylamino-anthraquinone.	
**Vistac No 1 is low MW polybutene; DOS is dioctylsebacate.	
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	22
Sample Wt, mg	19
Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
Rifle Bullet Impact Test: Trials %	
Explosions	
Partials	
Burned	
Unaffected	
Explosion Temperature: °C	
Seconds, 0.1 (no cap used)	
1	
5 Ignites	480
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	
Flammability Index:	
Hygroscopicity: %	0.31
71°C, 95% RH, 30 days	Satisfactory
Volatility:	

Molecular Weight:	
Oxygen Balance:	
CO_2 %	
CO %	
Density: gm/cc Loading	0.9
Melting Point: °C	
Freezing Point: °C	
Boiling Point: °C	
Refractive Index, n^{20}_{D}	
n^{25}_{D}	
n^{30}_{D}	
Vacuum Stability Test:	
cc/40 Hrs, at	
90°C	
100°C	
120°C	0.90
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	40.5
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.15
Ballistic Mortar, % TNT:	92
Trauzl Test, % TNT:	
Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detonation Rate:	
Confinement	None
Condition	Hand tamped
Charge Diameter, in.	1.25
Density, gm/cc	0.9
Rate, meters/second	4397; or 14400 ft/sec

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: Pink

Principal Uses: Excavation, demolition, and cratering

Method of Loading: Hall Packer machine loaded

Loading Density: gm/cc 0.9
Tamped cartridge 1-1/2" diameter, 8" long

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group A
Exudation	

Sensitivity to Initiation:

Stick dry, No. 6 Electric cap	Positive
Stick dry, Corps of Engineers	Positive
Stick wet, Corps of Engineers	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

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:

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

[25]See footnote 1, page 10.

Dynamite, Medium Velocity, Hercules (MVD)

Composition:

	%
RDX	75
TNT	15
Starch	5
SAE No. 10 Oil	4
Vistanex oil gel*	1

*80/15/5, SAE No. 10 weight oil/Vistanex B-120XC/Navy D2 wax.

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	>100
Sample Wt 20 mg	18
Picatinny Arsenal Apparatus, in.	25
Sample Wt, mg	

Friction Pendulum Test:

Steel Shoe	Crackles
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	0
Burned	10
Unaffected	90

Explosion Temperature: °C

Seconds, 0.1 (no cap used)

1

5

10

15

20

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.62
% Loss, 2nd 48 Hrs	0.12
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

71°C, 95% RH, 30 days — Satisfactory

Volatility:

Molecular Weight:

Oxygen Balance:

CO_2 %	-51
CO %	

Density: gm/cc — Loading 1.1

Melting Point: °C

Freezing Point: °C

Nitroglycerin Equivalent, % — 60

Refractive Index, n_D^{20}

n_D^{25}

n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	0.80
120°C	0.94
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm — 52.6

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT: 122

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement	None
Condition	Machine tamped
Charge Diameter, in.	1.50
Density, gm/cc	1.1
Rate, meters/second	6000-6100; or 20,000 ft/sec

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: Buff

Principal Uses: Excavation, demolition, and cratering

Method of Loading: Hall Packer machine loaded

Loading Density: gm/cc 1.1
Cartridge 1-1/2" diameter, 8" long

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group A
Exudation	

Sensitivity to Initiation:

Stick dry, No. 6 Electric cap	Positive
Stick dry, Corps of Engineers	Positive
Stick wet, Corps of Engineers	> 50% Positive

Air Gap Propagation:

Max distance will, inch	1
Min distance will not, inch	2-1/2

Quarry Performance: 4 tons rock/ton explosive

Stick Water Immersion:
Weight gain, % 25-27

Heat of:

Explosion, cal/gm	935
Gas Volume, cc/gm	945

Cold Storage: Plastic to -70°F

Low Temperature Usage:
-65°F, 1 day, M2 cap crimper Satisfactory

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.

[26]See footnote 1, page 10.

EC Blank Fire

Composition:	**Molecular Weight:** Approximately 503
%	**Oxygen Balance:**
Nitrocellulose, 13.25% N 80	CO_2 % +5
Barium Nitrate 8	CO % -25
Potassium Nitrate 8	**Density:** gm/cc
Starch 3	**Melting Point:** °C
Diphenylamine 0.75	**Freezing Point:** °C
Aurine 0.25	**Boiling Point:** °C
C/H Ratio	**Refractive Index,** n_{D}^{20}
Impact Sensitivity, 2 Kg Wt:	n_{D}^{25}
Bureau of Mines Apparatus, cm 19	n_{D}^{30}
Sample Wt 20 mg	**Vacuum Stability Test:**
Picatinny Arsenal Apparatus, in.	cc/40 Hrs, at
Sample Wt, mg 20	90°C
Friction Pendulum Test:	100°C
Steel Shoe Snaps	120°C
Fiber Shoe	135°C
Rifle Bullet Impact Test: Trials	150°C
%	**200 Gram Bomb Sand Test:**
Explosions	Sand, gm 46.8
Partials	**Sensitivity to Initiation:**
Burned	Minimum Detonating Charge, gm
Unaffected	Mercury Fulminate 0.22
Explosion Temperature: °C	Lead Azide
Seconds, 0.1 (no cap used)	Tetryl
1	**Ballistic Mortar, % TNT:**
5 Decomposes 200	**Trauzl Test, % TNT:**
10	**Plate Dent Test:**
15	Method
20	Condition
75°C International Heat Test:	Confined
% Loss in 48 Hrs 1.8	Density, gm/cc
100°C Heat Test:	Brisance, % TNT
% Loss, 1st 48 Hrs 2.0	**Detonation Rate:**
% Loss, 2nd 48 Hrs 0.2	Confinement
Explosion in 100 Hrs None	Condition
Flammability Index:	Charge Diameter, in.
Hygroscopicity: % 30°C, 90% RH 6.2	Density, gm/cc
Volatility:	Rate, meters/second

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

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.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Grenades; caliber .30 blank

Method of Loading: Loose

Loading Density: gm/cc 0.40

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 0
Compatibility Group	Group J
Exudation	

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.

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).

120°C Heat Test:

	Minutes
Salmon Pink	150
Red Fumes	300+
Explodes	300+

[27] See footnote 1, page 10.

Ednatol, 55/45

Composition:

	%
Haleite (Ethylene Dinitramine)	55
TNT	45

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	95
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
Sample Wt, mg	20

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	0
Burned	7
Unaffected	93

Explosion Temperature: *

		°C
Seconds, 0.1 (no cap used)		435
1		248
5	Decomposes	190
10		183
15		176
20		168

*Composition Haleite/TNT, 60/40.

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.2
% Loss, 2nd 48 Hrs	0.1
Explosion in 100 Hrs	None

Flammability Index: Will not continue to burn

Hygroscopicity: % None

Volatility:

Molecular Weight: 178

Oxygen Balance:

CO_2 %	-51
CO %	-17

Density: gm/cc Cast 1.62

Melting Point: °C Eutectic 80

Freezing Point: °C

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	1.0
120°C	11+
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm	49.4

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	0.22*
Lead Azide	0.26*
Tetryl	

*Alternative initiating charges.

Ballistic Mortar, % TNT: (a) 119

Trauzl Test, % TNT: (b) 120

Plate Dent Test: 52/48

Method	B
Condition	Cast
Confined	No
Density, gm/cc	1.62
Brisance, % TNT	112

Detonation Rate:

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.63
Rate, meters/second	7340

Fragment ~~ Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.56	1.62
Charge Wt, lb	2.065	2.092
Total No. of Fragments:		
For TNT	703	703
For Subject HE	842	902

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	536

Fragment Velocity: ft/sec

At 9 ft	2730
At 25½ ft	2430
Density, gm/cc	1.62

Blast (Relative to TNT): (d, e)

Air:	
Peak Pressure	108
Impulse	110
Energy	108
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	--
Impulse	--
Energy	113
Underground:	
Peak Pressure	
Impulse	
Energy	

Booster Sensitivity Test: (d)

Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	1.28
Density, gm/cc	1.62

Shaped Charge Effectiveness, TNT = 100: 50/50

	Glass Cones	Steel Cones
Hole Volume	126	123
Hole Depth	117	121

Color: Yellow

Principal Uses: Projectiles, bombs; special ammunition components

Method of Loading: Cast

Loading Density: gm/cc 1.65

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Does not exude at 65°C

Eutectic Temperature, °C: 79.8

gm Haleite/100 gm TNT	
79.8°C	0.48
95.0°C	1.12

Compatibility with Metals:

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

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

Preparation:

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

Origin:

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

References:[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 Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

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

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

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

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

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

[28] See footnote 1, page 10.

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

Composition:

%	
C	25.6
H	2.6
N	17.1
O	54.7

$CH_2CO_2CH_2CH_2C(NO_3)$
|
$CH_2CO_2CH_2CH_2C(NO_3)$

C/H Ratio 0.235

Impact Sensitivity, 2 Kg Wt:
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
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	50% point	230
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

Flammability Index:

Hygroscopicity: %

Volatility:

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

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
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.63
Rate, meters/second	7340

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-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:

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:

Temp, 98.9°C	0.246
106.5°C	0.193

Liquid Density, gm/cc:

Temp, 98.9°C	1.467
106.5°C	1.459

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).

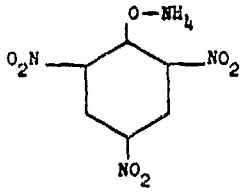
[29]See footnote 1, page 10.

Explosive D (Ammonium Picrate)

Composition:

	%
C	29.3
H	2.4
N	22.7
O	45.6

C/H Ratio 0.317



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	17
Sample Wt, mg	18

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	0
Burned	30
Unaffected	70

Explosion Temperature: °C

	°C
Seconds, 0.1 (no cap used)	405
1	367
5 Decomposes	318
10	314
15	299
20	295

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.1
% Loss, 2nd 48 Hrs	0.1
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 100% RH 0.1

Volatility:

Molecular Weight: ($C_6H_6N_4O_7$) 246

Oxygen Balance:

CO_2 %	-52
CO %	-13

Density: gm/cc Crystal 1.72

Melting Point: °C Decomposes 265

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_D

a₀ → a_0	1.508
b_0	1.870
c_0	1.907

Vacuum Stability Test:
cc/40 Hrs, at

90°C	
100°C	0.2
120°C	0.4
135°C	
150°C	0.4

200 Gram Bomb Sand Test:
Sand, gm 39.5

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.06

Ballistic Mortar, % TNT: (a) 99

Trauzl Test, % TNT:

Plate Dent Test:

Method	A
Condition	Pressed
C[illegible]ed	Yes
Density, gm/cc	1.50
Brisance, % TNT	91

Detonation Rate:

Confinement	None
Condition	Pressed
Charge Diameter, in.	1.0
Density, gm/cc	1.55
Rate, meters/second	6850

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

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-orange

Principal Uses: AP projectiles and bombs

Method of Loading: Pressed

Loading Density: gm/cc psi x 10^3

3	5	10	12	15	20
1.33	1.41	1.47	1.49	1.51	1.53

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None at 65°C

Sensitivity to Electrostatic Discharge, Joules: (d)

Through 100 Mesh:

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

Preparation:

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

Effect of Storage on Sand Test Values:

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

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

Solubility: gm/100 gm (%), of: (a)

Water °C	Water %	Alcohol °C	Alcohol %	Ethyl Acetate °C	Ethyl Acetate %
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 ($Na_2S \cdot 9H_2O$) 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 1945.

[30] See footnote 1, page 10.

(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.

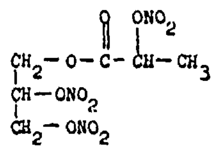
(f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

0	1	2	3	4	5	6	7	8	9
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				

Glycerol Monolactate Trinitrate (GLTN) Liquid

Composition:

	%
C	24.1
H	3.0
N	14.1
O	58.8



C/H Ratio 0.180

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

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	223
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	2.5
% Loss, 2nd 48 Hrs	1.8
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility: 60°C, mg/cm^2/hr 28

Molecular Weight: ($C_6H_9N_3O_{11}$) 299

Oxygen Balance:

CO_2 %	-30
CO %	3

Density: gm/cc Liquid 1.47

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index,

n_{20}^{D}	
n_{25}^{D}	1.44
n_{30}^{D}	

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	5.9
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm 13.1

Sensitivity to Initiation:

Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl 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

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:

Principal Uses: Gelatinizer for nitrocellulose

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Liquid
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Hydrolysis, % Acid:

10 days at 22°C	0.021
5 days at 60°C	0.014

Solubility in Water, gm/100 gm, at:

25°C	<0.01
60°C	<0.015

Solubility, gm/100 gm, at 25°C, in:

Ether	-
2:1 Ether:Alcohol	-
Acetone	-

Heat of:

Combustion, cal/gm	2407

Glycerol Monolactate Trinitrate (GLTN) Liquid

Preparation:

Glycerol monolactate (GML) is prepared by heating a glycerol lactic acid mixture containing 4% excess lactic acid at 116°C for 112 hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of 40/60 HNO_3/H_2SO_4 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]

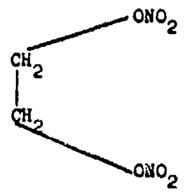
(a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, PATR No. 1616, 22 July 1946.

[31] See footnote 1, page 10.

Glycol Dinitrate (GDN) Liquid

Composition:

	%
C	15.8
H	2.6
N	18.4
O	63.2



C/H Ratio 0.092

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

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	Explodes	257
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

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.00

Volatility:

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

Boiling Point: °C

Refractive Index, n^D_{20}
n^D_{25} 1.4452
n^D_{30}

Vacuum Stability Test:
cc/40 Hrs, at
90°C
100°C
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	Glass tube
Condition	Liquid
Charge Diameter, in.	10
Density, gm/cc	1.485
Rate, meters/second	7300 and 2050

Glycol Dinitrate (GlN) 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

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

Principal Uses: Ingredient of nonfreezing dynamite

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Liquid
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Solubility in 1000 cc Water:

Temp, °C	Grams
15	6.2
20	6.8
50	9.2

Viscosity, centipoises:

Temp. 20°C 4.2

Vapor Pressure:

°C	mm Mercury
0	0.0044
20	0.038
40	0.26
60	1.3
80	5.9
100	22.0

Heat of:

Combustion, cal/gm		1764
Formation, cal/gm	(b)	366

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, $HOCH_2CH_2OH$, 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:

$$CH_2 = CH_2 \xrightarrow{HOCl} HOCH_2CH_2Cl \xrightarrow[NaHCO_3]{H_2O} HOCH_2CH_2OH$$

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 1624, 27 August 1946.

[32] See footnote 1, page 10.

H-6

Composition:

	%
RDX	45
TNT	30
Aluminum	20
D-2 Wax	5
Calcium Chloride, added	0.5
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in. (c)	14
Sample Wt, mg	18

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	---

Rifle Bullet Impact Test: Trials (b)

	%
Explosions	80
Partials	--
Burned	--
Unaffected	20

Explosion Temperature: °C (a)

Seconds,	°C
0.1 (no cap used)	---
1	---
5	610(min) (c)
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.78
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

30°C, 95% RH, 7 days	2.01
71°C, 95% RH, 7 days	1.77

Volatility:

Molecular Weight: 93

Oxygen Balance:

CO_2 %	-66
CO %	-36

Density: gm/cc Cast 1.74

Melting Point: °C

Freezing Point: °C

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	0.47
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 49.5

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT: (d) 135

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate: (a, b)

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.71
Rate, meters/second	7191

Booster Sensitivity Test:	
Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	
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
Specific Heat: cal/gm/°C	(b)
30°C	0.269
50°C	0.268
Burning Rate:	
cm/sec	
Thermal Conductivity:	(b)
cal/sec/cm/°C 35°C	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/cm²	9.0×10^{9}
E, lb/inch²	1.30×10^{5}
Density, gm/cc	1.71
Compressive Strength: lb/inch²	See below
Vapor Pressure:	
°C mm Mercury	
Compressive Strength: lb/inch²	1083
Density, gm/cc	1.71
Ultimate deformation, %	1.32

Decomposition Equation:	
Oxygen, atoms/sec	
(Z/sec)	
Heat, kilocalorie/mole	
(ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	

H-6

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

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

(Reference e)

Explosive	Simulated Altitude, Feet	One-Inch Column Confined m/s	One-Inch Column Unconfined m/s	Two-Inch Column Confined m/s	Two-Inch Column Unconfined 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	6870
	30,000	7300(2)	7430	7360	7980
	60,000	7280	7490	7550	7010
	90,000	7300(3)	7270	7500	7000
Average		7268	7385	7438	7215

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

Average Fragment Velocities at Various Altitudes* (e)

Explosive	Charge Diameter, Inches	Simulated Altitude, Feet: Ground m/s	30,000 m/s	60,000 m/s	90,000 m/s
TNT, density, gm/cc 1.51	1	2940	2991	3119	2868
	2	3623	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.

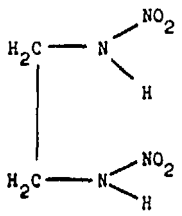
Haleite (Ethylene Dinitramine) (EDNA)

(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



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	48
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	14
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	60
Burned	20
Unaffected	20

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	265
1	216
5 Decomposes	189
10	178
15	173
20	170

75°C International Heat Test:

% Loss in 48 Hrs 0.01

100°C Heat Test:

% Loss, 1st 48 Hrs	0.2
% Loss, 2nd 48 Hrs	0.3
Explosion in 100 Hrs	None

Flammability Index: 138

Hygroscopicity: % 0.01

Volatility: Nil

Molecular Weight: ($C_2H_6N_4O_4$) 150

Oxygen Balance:

CO_2 %	-32
CO %	-10.5

Density, gm/cc Crystal 1.71

Melting Point: °C Decomposes 175+

Freezing Point: °C

Boiling Point: °C

Refractive Index, n^{20}_{D}

n^{25}_{D}

n^{30}_{D}

Vacuum Stability Test:

cc/40 Hrs, at

90°C	
100°C	0.5
120°C	1.5
135°C	--
150°C	11+

200 Gram Bomb Sand Test:

Sand, gm 52.3

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	0.21
Lead Azide	0.13
Tetryl	--

Ballistic Mortar, % TNT: (a) 139

Trauzl Test, % TNT: (b) 122

Plate Dent Test: (c)

Method	A
Condition	Pressed
Confined	Yes
Density, gm/cc	1.50
Brisance, % TNT	122

Detonation Rate:

Confinement	Unconfined
Condition	Pressed
Charge Diameter, in.	1.0
Density, gm/cc	1.49
Rate, meters/second	7570

Haleite (Ethylene Dinitramine) (EDNA)

Booster Sensitivity Test:

	(d)
Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	2.09
Wax, gm	
Density, gm/cc	1.42

Heat of:

Combustion, cal/gm	2477
Explosion, cal/gm	1276
Gas Volume, cc/gm	908
Formation, cal/gm	134
Fusion, cal/gm	

Specific Heat: cal/gm/°C

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

Decomposition Equation:

	(e)	(e)	(f)
Oxygen, atoms/sec (Z/sec)	$10^{12.8}$	$10^{12.1}$	$10^{11.1}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	30.5	37.3	30.8
Temperature Range, °C	184-254	--	144-164
Phase	Liquid	Solid	Solid

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

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

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:

	95/5 Haleite/wax
Density, gm/cc	1.56
Charge Wt, lb	--

Total No. of Fragments:

For TNT	514
For Subject HE	600

Fragment Velocity: ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

Blast (Relative to TNT):

Air:

Peak Pressure

Impulse

Energy

Air, Confined:

Impulse

Under Water:

Peak Pressure

Impulse

Energy

Underground:

Peak Pressure

Impulse

Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses: Booster

Method of Loading: Pressed

Loading Density: gm/cc psi x 10^3

5	10	12	15	20
1.28	1.38	1.41	1.44	1.49

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

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:

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

Solubility: gm/100 gm (%) of:

Water		Alcohol	
°C	%	°C	%
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)

$$CH_2O + HCN \rightarrow HO\ CH_2CN$$

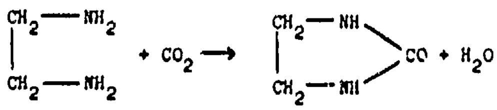
(98% yield)

$$HO\ CH_2CN + NH_3 \rightarrow NH_2CH_2CN + H_2O$$

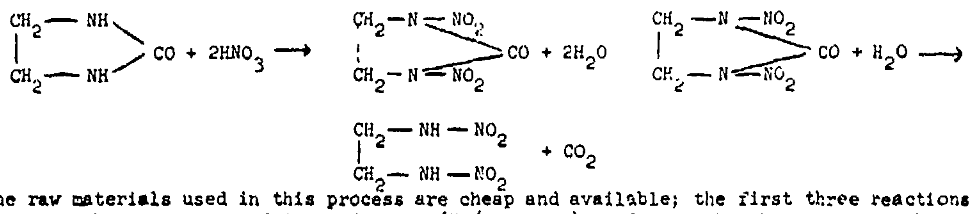
(82% yield)

$$NH_2CH_2CN + 2H_2 \rightarrow H_2N\ CH_2CH_2NH_2$$

(88% yield)



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 120 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl 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 (98%). 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 RDX/Wax Mixtures as a Substitute for Tetryl 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 Abbeg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

[33]See footnote 1, page 10.

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

0	1	2	3	4	5	6	7	8	9
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

HBX-1

Composition:	
	%
RDX	40
TNT	38
Aluminum	17
D-2 Wax	5
Calcium Chloride, added	0.5
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	16
Sample Wt, mg	21

Friction Pendulum Test: (b)	
Steel Shoe	Unaffected
Fiber Shoe	---

Rifle Bullet Impact Test:	Trials	(b)
	%	
Explosions	73	
Partials	--	
Burned	--	
Unaffected	28	

Explosion Temperature:	°C	(a)
Seconds, 0.1 (no cap used)	---	
1	---	
5	430	
10		
15		
20		

75°C International Heat Test:	
% Loss in 48 Hrs	

100°C Heat Test:	(b)
% Loss, 1st 48 Hrs	0.058
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 95% RH, 7 days	2.98
71°C, 95% RH, 7 days	1.13

Volatility:

Molecular Weight:		102
Oxygen Balance:		
CO_2 %		-68
CO %		-35
Density: gm/cc	Cast	1.72
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:	(a, b)
cc/40 Hrs, at	
90°C	----
100°C	0.47
120°C	0.98
135°C	----
150°C	11+

200 Gram Bomb Sand Test:	
Sand, gm	48.1

Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT:	(a)	133
Trauzl Test, % TNT:		

Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	

Detonation Rate:	(a, b)
Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.69
Rate, meters/second	7224

Property	Value
Booster Sensitivity Test:	(c)
Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	1.25
Wax, gm	
Density, gm/cc	1.73
Heat of:	(b)
Combustion, cal/gm	3802
Explosion, cal/gm	919
Gas Volume, cc/gm	
Formation, cal/gm	758
Fusion, cal/gm 78°C	9.25
Specific Heat: cal/gm/°C	(b)
30°C	0.249
50°C	0.264
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C 35°C	(b) 0.97 x 10^{-3}
Coefficient of Expansion:	(b)
Linear, $\Delta \ell$/inch	
0°C	46 x 10^{-4}
35°C	95 x 10^{-4}
70°C	159 x 10^{-4}
Hardness, Mohs' Scale:	
Young's Modulus:	(b)
E', dynes/cm²	10.3 x 10^{9}
E, lb/inch²	1.49 x 10^{-5}
Density, gm/cc	1.69
Compressive Strength: lb/inch²	See below
Vapor Pressure:	
°C mm Mercury	
Compressive Strength: lb/inch²	(b) 1303
Density, gm/cc	1.69
Ultimate deformation, %	1.38

Property	Value
Decomposition Equation:	
Oxygen, atoms/sec (Z/sec)	
Heat, kilocalorie/mole (ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	

Fragmentation Test:	(b)	**Shaped Charge Effectiveness, TNT = 100:**	
90 mm HE, M71 Projectile, Lot EOS-1-17:			Glass Cones / Steel Cones
Density, gm/cc		Hole Volume	
Charge Wt, lb		Hole Depth	
Total No. of Fragments:		**Color:**	Gray
For Composition B	998	**Principal Uses:**	HE charge
For Subject HE	910		
For 80/20 Tritonal	616		
3 inch HE, M42A1 Projectile, Lot KC-5:		**Method of Loading:**	Cast
Density, gm/cc		**Loading Density:** gm/cc	1.69
Charge Wt, lb		**Storage:**	
Total No. of Fragments:		Method	Dry
For TNT		Hazard Class (Quantity-Distance)	Class 9
For Subject HE		Compatibility Group	Group I
Fragment Velocity: ft/sec		Exudation	None
At 9 ft			
At 25½ ft			
Density, gm/cc			
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			

Composition:	%	
RDX	31	
TNT	29	
Aluminum	35	
D-2 Wax	5	
Calcium Chloride, added	0.5	
C/H Ratio		

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15
Sample Wt, mg	23

Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	---

Rifle Bullet Impact Test:	Trials	(b)
	%	
Explosions	78	
Partials	--	
Burned	--	
Unaffected	22	

Explosion Temperature:	°C	(a)
Seconds, 0.1 (no cap used)	---	
1	---	
5	500	
10		
15		
20		

75°C International Heat Test:	
% Loss in 48 Hrs	

100°C Heat Test:	(b)
% Loss, 1st 48 Hrs	0.70
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % (b)		
	30°C, 95% RH, 7 days	2.01
	71°C, 95% RH, 7 days	0.31

Volatility:

Molecular Weight:		64

Oxygen Balance:	
CO_2 %	-75
CO %	-49

Density: gm/cc	Cast	1.84

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D} n_{25}^{D} n_{30}^{D}

Vacuum Stability Test:	(a, b)
cc/40 Hrs, at	
90°C	----
100°C	0.45
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:	(b)
Sand, gm	44.9

Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.10

Ballistic Mortar, % TNT:	(d)	111

Trauzl Test, % TNT:

Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	

Detonation Rate:	(a, b)
Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.81
Rate, meters/second	6917

HBX-3

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:	(b)
Combustion, cal/gm	4495
Explosion, cal/gm	877
Gas Volume, cc/gm	
Formation, cal/gm	491
Fusion, cal/gm	9.30

Specific Heat: cal/gm/°C	
30°C	0.254
50°C	0.254

Burning Rate:
cm/sec

Thermal Conductivity:	(b)
cal/sec/cm/°C 35°C	1.70×10^{-3}

Coefficient of Expansion:	(b)
Linear, $\Delta \ell$/inch	
0°C	40×10^{-4}
35°C	83×10^{-4}
70°C	130×10^{-4}

Hardness, Mohs' Scale:

Young's Modulus:	(b)
E', dynes/cm²	11.5×10^{9}
E, lb/inch²	1.67×10^{5}
Density, gm/cc	1.81

Compressive Strength: lb/inch² See below

Vapor Pressure:
°C mm Mercury

Compressive Strength: lb/inch²	1610
Density, gm/cc	1.81
Ultimate deformation, %	1.37

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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

Fragment Velocity: ft/sec

At 9 ft

At 25½ ft

Density, gm/cc

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

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Gray

Principal Uses: HE charge

Method of Loading: Cast

Loading Density: gm/cc 1.81

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None

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

Explosive Composition	Moisture, %	Acidity, %	100°C Vac Stab Test cc gas	100°C Vac Stab Test Hours	Hygroscopicity, % 95% RH 30°C	Hygroscopicity, % 95% RH 71°C
Standard HBX-1	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		
HBX-1 without $CaCl_2$	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		
HBX-1 with silica gel	0.06	0.031	0.73	40	+0.08	+0.04
Standard HBX-3	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		
HBX-3 without $CaCl_2$	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		
HBX-3 with silica gel	0.04	0.100	0.45	40	+0.09	+0.05
Standard H-6	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		
H-6 without $CaCl_2$	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		
H-6 with silica gel	0.05	0.028	0.43	40	+0.09	+0.06

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

HBX-1; HBX-3

Preparation:

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 1956.

(b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.

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

(d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, NAVORD Report No. 1502, 26 July 1950.

(e) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

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

[34]See footnote 1, page 10.

Composition: %		**Molecular Weight:**	47.6
Potassium Perchlorate (17 microns)	32	**Oxygen Balance:**	
Aluminum, atomized (20 microns)	48	CO_2 %	-42
RDX (through 325 mesh)	16	CO %	-34
Asphaltum (through 100 mesh)	4	**Density:** gm/cc Apparent	1.39
		Pressed at 20,000 psi	2.1
C/H Ratio		**Melting Point:** °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		**Boiling Point:** °C	
Bureau of Mines Apparatus, cm	--	**Refractive Index,** n_D^{20}	
Sample Wt 20 mg		n_D^{25}	
Picatinny Arsenal Apparatus, in.	16	n_D^{30}	
Sample Wt, mg	24		
Friction Pendulum Test:		**Vacuum Stability Test:**	
Steel Shoe	Detonates	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
Rifle Bullet Impact Test: Trials		100°C	1.25
%		120°C	
Explosions		135°C	
Partials		150°C	
Burned		**200 Gram Bomb Sand Test:**	
Unaffected		Sand, gm	12.5
Explosion Temperature: °C		**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5	520	Lead Azide	0.20
10		Tetryl	0.25
15		**Ballistic Mortar, % TNT:**	
20		**Trauzl Test, % TNT:**	
75°C International Heat Test:		**Plate Dent Test:**	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.15	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		**Detonation Rate:**	
		Confinement	
Hygroscopicity: %	None	Condition	
		Charge Diameter, in.	
Volatility:	None	Density, gm/cc	
		Rate, meters/second	

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

Flame Temperature, °K	2552
Activation Energy, kcal	20.4
Temp, °C	450 to 570
Specific reaction rate, k	1.64×10^{-5}

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Gray

Principal Uses: HE filler for small caliber projectiles

Method of Loading: Pressed

Loading Density: gm/cc
Pressed at 20,000 psi 2.1

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	None

Static Tests:
20 mm T215E1 Projectile:

PA Peak Pressure, psi	55
NFOC 20" Blast Cube	44
APG 24" Blast Cube	44

Static Tests:
20 mm M97 Projectile:

	HEX-24	Tritonal	Torpex
Foxboro psi	19	12.4	13.0
Catenary psi	46	----	----
Duration, microsec	533	----	----
APG 24" Blast Cube	36	24	32

Heat of:

Combustion, cal/gm	4197
Explosion, cal/gm	1858
Gas volume, cc/gm	159

HEX-48

Composition: %		**Molecular Weight:**	47.6
Potassium Perchlorate (17 microns)	32	**Oxygen Balance:**	
Aluminum, flaked (1 micron)	48	CO_2 %	-42
RDX (through 325 mesh)	16	CO %	-34
Asphaltum (through 100 mesh)	4	**Density:** gm/cc Apparent	0.69
		Pressed at 20,000 psi	1.62
		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^{20}_{D}	
Sample Wt 20 mg		n^{25}_{D}	
Picatinny Arsenal Apparatus, in.		n^{30}_{D}	
Sample Wt, mg			
Friction Pendulum Test:		**Vacuum Stability Test:**	
Steel Shoe	Partially detonates	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
Rifle Bullet Impact Test: Trials		100°C	1.52
	%	120°C	
Explosions		135°C	
Partials		150°C	
Burned		**200 Gram Bomb Sand Test:**	
Unaffected		Sand, gm	23.7
Explosion Temperature:	°C	**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5	545	Lead Azide	0.20
10		Tetryl	0.25
15		**Ballistic Mortar, % TNT:**	
20		**Trauzl Test, % TNT:**	
75°C International Heat Test:		**Plate Dent Test:**	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
Flammability Index:		**Detonation Rate:**	
Hygroscopicity: %		Confinement	
		Condition	
		Charge Diameter, in.	
Volatility:		Density, gm/cc	
		Rate, meters/second	

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	

Flame Temperature, °K	2382
Activation Energy, kcal	25.4
Temp, °C	450 to 470
Specific reaction rate, k	7.94×10^{-6}

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Gray

Principal Uses: HE filler for small caliber projectiles

Method of Loading: Pressed

Loading Density: gm/cc

Pressed at 20,000 psi	1.62

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	None

Static Tests:

20 mm T215E1 Projectile:

BA Peak Pressure, psi	77
NFCC 20" Blast Cube	45
APG 24" Blast Cube	42

Static Tests:

20 mm M97 Projectile:

	HEX-48	TNT	Tetryl
Footoro psi	17.3	2.8	3.5
Catenary psi	43	28	28
Duration, microsec	517	560	530
APG 24" Blast Cube	29	---	10

Heat of:

Combustion, cal/gm	4119
Explosion, cal/gm	1735
Gas Volume, cc/gm	200

Cook-Off Tests: (c)

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

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

National Northern Projectile Load:

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

Fragment Penetration Tests: (c)

Projectile	Filler	Altitude, Feet	Avg. No. of Penetrations per Round in Zone 65°-130° 0.020"	0.040"	0.051"
T215E1	HEX-48	Ground	352	264	282
		60,000	676	432	398
T282E1	MOX-2B	Ground	634	290	235
		60,000	807	367	250
EX8 Mod 0	MOX-2B	Ground	476	268	224
		60,000	672	264	256

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

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

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 obtained 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.

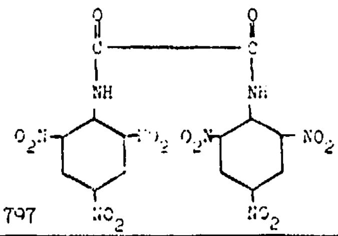
[35]See footnote 1, page 10.

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



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15
Sample Wt, mg	12

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	--
1	--
5	394
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

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:

Molecular Weight: ($C_{14}H_6N_8O_{14}$)

Oxygen Balance:

CO_2 %	-53.4
CO %	- 9.4

Density: gm/cc

Melting Point: °C Decomposes 302

Freezing Point: °C

Boiling Point: °C

Refractive Index, n^{o}_{20}
n^{o}_{25}
n^{o}_{30}

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

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	--
Lead Azide	0.30
Tetryl	0.25

Ballistic Mortar, % TNT:

Trauzl 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

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: Almost white
	Principal Uses: Igniter powder; pyrotechnic compositions
	Method of Loading: Pressed and extruded
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	**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:** Method: Dry Hazard Class (Quantity-Distance): Class 9 Compatibility Group Exudation: None

Solubility in the following substances:

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

Preparation:

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

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

Origin:

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

References:[36]

(a) L. Gowen and R. Dwiggens, 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.

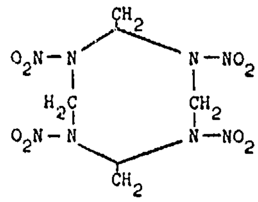
(c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136,330, 11 April 1951.

(d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.

[36]See footnote 1, page 10.

Composition:

%	
C	16.2
H	2.7
N	37.9
O	43.2



C/H Ratio 0.095

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	32
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	9
Sample Wt, mg	23

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	380
1	--
5	327
10	306
15	--
20	--

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.05
% Loss, 2nd 48 Hrs	0.03
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %
30°C, 95% RH (c) 0.00

Volatility:

Molecular Weight: ($C_4H_8N_8O_8$) 296

Oxygen Balance:

CO_2 %	-21.6
CO %	0.0

Density: gm/cc Crystal 1.90

Melting Point: °C Capillary method 273; Kofler Micro Hot Stage 280

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	0.37
120°C	0.45
135°C	--
150°C	0.62

200 Gram Bomb Sand Test:
Sand, gm 60.4

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.30
Tetryl	

Ballistic Mortar, % TNT: 150

Trauzl Test, % TNT: 145

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.84
Rate, meters/second	9124

Booster Sensitivity Test:

Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	

Heat of:

Combustion, cal/gm		2362
Explosion, cal/gm	(e)	1356
Gas Volume, cc/gm		
Formation, cal/gm	(e)	-60.5
Fusion, cal/gm		

Specific Heat: cal/gm/°C — Recrystallized (g)

°C		°C	
-75	0.153	85	0.288
0	0.228	90	0.290
25	0.248	100	0.295
50	0.266	125	0.307
75	0.282	150	0.315

Burning Rate:
cm/sec

Thermal Conductivity:
cal/sec/cm/°C

Coefficient of Expansion:
Linear, %/°C

Volume, %/°C

Hardness, Mohs' Scale: (e) 2.3

Young's Modulus:
E', dynes/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure:
°C mm Mercury

Decomposition Equation:

Oxygen, atoms/sec (Z/sec)	(e) $10^{19.7}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	52.7
Temperature Range, °C	271-314
Phase	Liquid

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

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

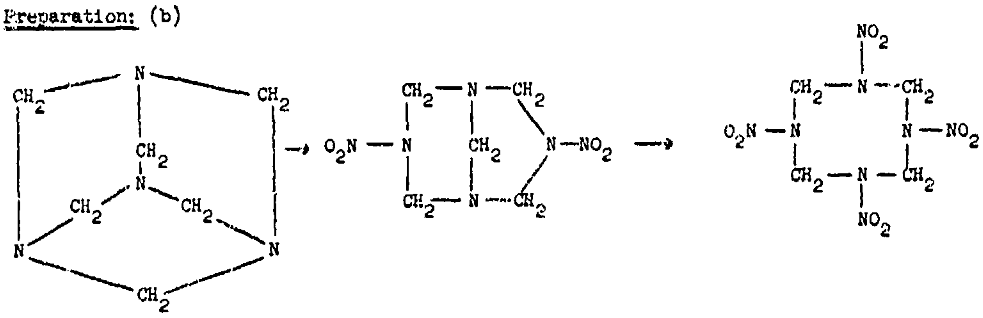
500-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

1000-lb General Purpose Bomb vs Concrete:

Height, ft
Trials
Unaffected
Low Order
High Order

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 burrettes 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 ± 1°C, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride and 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

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

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

Procedure:

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

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the 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 RXD 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.

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-TM1-23, 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. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(e) O. H. Johnson, HMX as a Military Explosive, NAVORD Report No. 4371, 1 October 1956.

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

1	3	6	7	9
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 1959.

[37]See footnote 1, page 10.

HTA-3

Composition:	
%	
HMX	49
TNT	29
Aluminum	22
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	17
Sample Wt, mg	25

Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 10 Trials, %	3/16" Steel	1/8" Al
Explosions	90	50
Partials	--	--
Burned	10	--
Unaffected	0	50

Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	---
1	---
5 Flames erratically	370
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

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight:		91
Oxygen Balance:		
CO_2 %		-51
CO %		-27
Density: gm/cc	Cast	1.90
Melting Point: °C		
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		

Vacuum Stability Test:	
cc/40 Hrs, at	
90°C	----
100°C	----
120°C	0.37
135°C	
150°C	

200 Gram Bomb Sand Test:	
Sand, gm	61.3

Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.30
Tetryl	----

Ballistic Mortar, % TNT.	120
Trauzl Test, % TNT:	

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:	
Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.90
Rate, meters/second	7866

Booster Sensitivity Test:	
Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	
Heat of:	
Combustion, cal/gm	3687
Explosion, cal/gm	1190
Gas Volume, cc/gm	680
Formation, cal/gm	----
Fusion, cal/gm	
Specific Heat: cal/gm/°C	
32° to 74°C	0.245
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	2260 See below
Vapor Pressure:	
°C mm Mercury	
Compressive Strength: lb/inch²	*
Average (10 tests)	2260
High	2530
Low	1910

Decomposition Equation:	
Oxygen, atoms/sec	
(Z/sec)	
Heat, kilocalorie/mole	
(ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	
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.

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Gray
For TNT	
For Subject HE	**Principal Uses:** HE projectile and bomb filler
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Cast
For TNT	
For Subject HE	**Loading Density:** gm/cc 1.90
Fragment Velocity: ft/sec	**Storage:**
At 9 ft	Method: Dry
At 25½ ft	Hazard Class (Quantity-Distance): Class 9
Density, gm/cc	Compatibility Group: Group I
Blast (Relative to TNT):	Exudation: None
Air:	Work to Produce Rupture: ft-lb/inch^3 *
Peak Pressure	Average (10 tests) 2.77
Impulse	High 3.39
Energy	Low 2.40
Air, Confined:	Efflux Viscosity, Saybolt Seconds: 24.8
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	
	*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.

Modulus of Elasticity: *

	lb/inch²
Average	89,200
High	97,400
Low	76,300

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

Setback Sensitivity Test: (a)

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

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

Preparation:

Procedure similar to that used for Torpex.

References:[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-H1-509, 5 May 1958.

[38]See footnote 1, page 10.

Composition:

%	
N	28.8
Pb	71.2

N≡N—N—Pb—N—N≡N

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

	Pure	Dextrinated
Bureau of Mines Apparatus, cm	10	17
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	3	5
Sample Wt, mg	30	28

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber 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: %

	Dextrinated	Not Dextrinated
30°C, 90% RH	0.[illegible]	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_D^{20}

n_D^{25}

n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at	Dextrinated
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:

Trauzl Test, % TNT: (a) 39

Plate Dent Test:

- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

Detonation Rate: Pure Lead Azide

Confinement			
Condition	Pressed		
Charge Diameter, in.			
Density, gm/cc	2.0	3.0	4.0
Rate, meters/second	4070	4630	5180

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

Heat of:

Combustion, cal/gm	630
Explosion, cal/gm	367
Gas Volume, cc/gm	308
Formation, cal/gm	-346

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White-buff

Principal Uses: Detonators, priming compositions, and commercial blasting caps

Method of Loading: Pressed

Loading Density: gm/cc

psi x 10^3	3	5	10	15
	2.62	2.71	2.96	3.07

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M (wet)
Exudation	None

Compatibility with Metals:

Dry lead azide does not react with or corrode steel, iron, nickel, aluminum, lead, zinc, copper, tin or cadmium. It does not affect coatings of acid-proof black paint, oil, NRC compound or shellac. Lead azide in the presence of moisture corrodes zinc and copper; and with copper, it forms the extremely sensitive and dangerous copper azide.

Specific Heat: cal/gm/°C

°C	
-50	0.110
0	0.110
25	0.110
50	0.110

Thermal Conductivity:

cal/sec/cm/°C (Pure) 1.55×10^{-4}

Compatibility with Metals:

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

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide (½% moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-aluminum alloy is very slightly corroded.

Sample Tested	Lead Azide Dry	Lead Azide plus 25% Water		Lead Azide plus 20% Water		Lead Azide plus 20% Ethyl Alcohol (95%)
Friction Pendulum Test:						
(All LA dextrinated)						
Shoe	Fiber	Fiber	Steel	Fiber	Steel	Fiber
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

Activation Energy: (c)

Kcal/mole	23.74
Induction Period, seconds	0.5-10

Initiating Efficiency, Grams Required to Give Complete Initiations of:

	Dextrinated Azide (gm)
TNT	0.25
Tetryl	0.10
RDX	0.05
PETN	0.02

Sensitivity to Static Discharge, Joules (Pure Lead Azide) (b) 0.0070

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

Sample Wt (gm)	Material	cc
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:

°C	%
20	0.05

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

$$2\ Na-N=N\equiv N + Pb\ (NO_3)_2 \rightarrow Pb(N_3)_2 + 2\ NaNO_3$$

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

(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:

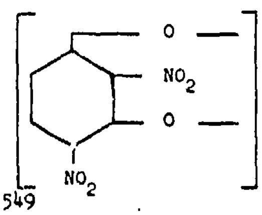
0	1	2	3	4	5	6	7	8	9
550	561	832	393	534	255	326	567	628	609
580	861	852	1393	784	525	856	637	708	719
600	1451	882	1493	824	1325	866	657	748	749
760	1651	932	2093	944	1485	1316	707	788	769
1450		1132	2133	2164		1486	1737	838	849
		1152		2204		1556	2227	1388	999
		1352						1528	2179
		1372						1838	
								2198	

39 See footnote 1, page 10.

Lead 2,4-Dinitroresorcinate (LDNR)

Composition:

	%
C	17.8
H	0.5
N	6.9
O	23.7
Pb	51.1



C/H Ratio 0.549

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

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 Explodes 265
10
15
20

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:
% Loss, 1st 48 Hrs 0.20
% Loss, 2nd 48 Hrs 0.02
Explosion in 100 Hrs None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.73

Volatility:

Molecular Weight: ($PbC_6H_2N_2O_6$) 405

Oxygen Balance:
CO_2 % -32
CO % - 8

Density: gm/cc Crystal 3.2

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}
n_{25}^{D}
n_{30}^{D}

Vacuum Stability Test:
cc/40 Hrs, at
90°C
100°C
120°C (73 minutes) Explodes
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm
Black powder fuse 20

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl 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

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: Red or yellow

Principal Uses: Electric detonators

Method of Loading: Pressed

Loading Density: gm/cc

Storage:

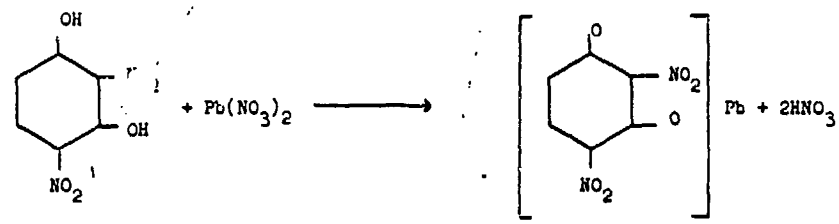
Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

Initiating Efficiency: 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi.

Heat of:

Explosion, cal/gm 270

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:

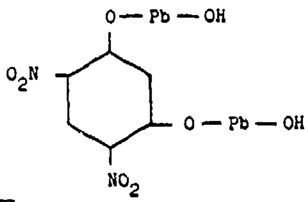
0	3	4	8	9
480	453	1004	1328	859
580			1448	1079

[40]See footnote 1, page 10.

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

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

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 Explodes 295
10
15
20

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:
% Loss, 1st 48 Hrs 0.4
% Loss, 2nd 48 Hrs 0.0
Explosion in 100 Hrs None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: ($Pb_2C_6H_4N_2O_8$) 646

Oxygen Balance:
CO_2 % -20
CO % - 5

Density: gm/cc

Melting Point: °C 213

Freezing Point: °C

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
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm Black powder fuse 15

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

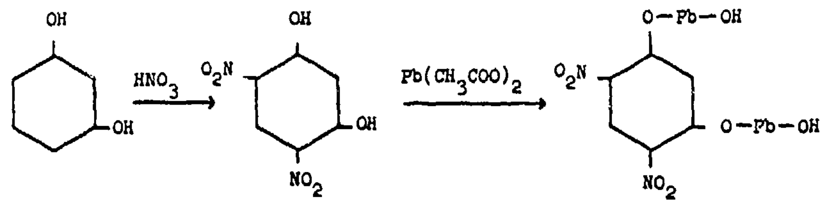
Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Red or yellow
For TNT	
For Subject HE	**Principal Uses:** Electric detonators
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Pressed
For TNT	
For Subject HE	**Loading Density:** gm/cc
Fragment Velocity: ft/sec	**Storage:**
At 9 ft	Method: Wet
At 25½ ft	Hazard Class (Quantity-Distance): Class 9
Density, gm/cc	Compatibility Group
Blast (Relative to TNT):	Exudation: None
Air:	Initiating Efficiency: 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 psi.
Peak Pressure	
Impulse	
Energy	
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	

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.

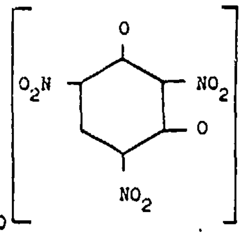
Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke 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-Dinitroresorcinate"). 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

Composition:

%	
C	15.4
H	0.6
N	9.0
O	30.8
Pb	44.2



PbH_2O

C/H Ratio 0.320

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

Friction Pendulum Test:

Steel Shoe	Detonates
Fiber Shoe	Detonates

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		
1		
5	Explodes	282
10		276
15		272
20		267

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.38
% Loss, 2nd 48 Hrs	0.73
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

25°C, 100% RH	0.05
30°C, 90% RH	0.02

Volatility:

Molecular Weight: ($PbC_6H_3N_3O_9$) 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

Refractive Index, n_D^{20} n_D^{25} n_D^{30}

Vacuum Stability Test:
cc/40 Hrs, at

90°C	
100°C	0.4
120°C	0.3
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm	24
Black powder fuse	11.1

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	Trace*
Lead Azide	Trace*
Tetryl	

* <.001 gm, alternative

Ballistic Mortar, % TNT:

Trauzl Test, % TNT: (a) 40

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	2.9
Rate, meters/second	5200

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

Heat of:

Combustion, cal/gm	1251
Explosion, cal/gm	457
Gas Volume, cc/gm	368
Formation, cal/gm	-92

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Orange-reddish brown

Principal Uses: Igniting charge, and ingredient of priming compositions

Method of Loading: Pressed

Loading Density: gm/cc

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M (wet)
Exudation	None

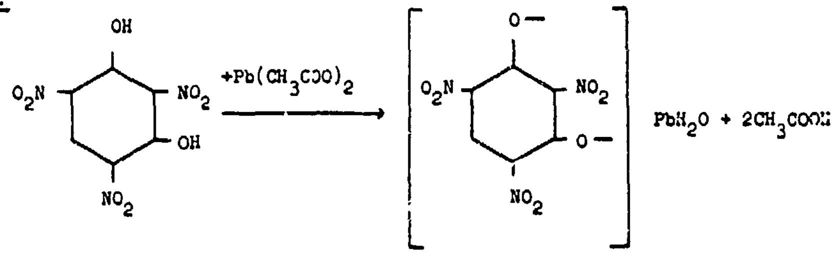
Activation Energy:

kcal/mol	75.39
Induction Period, sec	0.5-10

Specific Heat: cal/cm/°C (c)

°C	
-50	0.141
0	0.158
25	0.164
50	0.167

Preperation:



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	Nil
Sand Test Value	Nil
Sensitivity to Initiation	Nil

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)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasan (Russia) 2, 81-5 (1935).

Destruction by Chemical Decomposition:

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

References:[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:

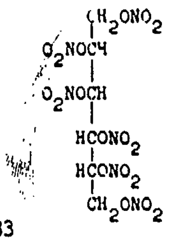
0	1	2	3	4	6	7	8	9
1450	11	1352	453	2164	1316	407	318	2179
2220		2032	2093			1737		
						2077		

[41]See footnote 1, page 10.

Composition:

%	
C	15.9
H	1.8
N	18.6
O	63.8

C/H Ratio 0.133



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	11
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	4
Sample Wt, mg	11

Friction Pendulum Test:

Steel Shoe	Detonates
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	160-170	(a)
1	232	(b)
5	175	(c)
10		
15		
20		

75°C International Heat Test:

% Loss in 48 Hrs 0.4

100°C Heat Test:

% Loss, 1st 48 Hrs	--
% Loss, 2nd 48 Hrs	--
Explosion in 100 Hrs (Frothed)	48 hours

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.17

Volatility:

Molecular Weight: ($C_6H_8N_6O_{18}$) 452

Oxygen Balance:

CO_2 %	7.1
CO %	28.3

Density: gm/cc 1.73

Melting Point: °C 112-113

Freezing Point: °C

Boiling Point: °C Decomposes 150

Refractive Index, n_D^{20}

n_D^{25}

n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at

90°C

100°C

120°C

135°C

150°C

200 Gram Bomb Sand Test:

Sand, gm 68.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	--
Lead Azide	0.06
Tetryl	--

Ballistic Mortar, % TNT:

Trauzl Test, % TNT: (c) 172

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate: (d)

Confinement	Yes
Condition	Pressed
Charge Diameter, in.	0.5
Density, gm/cc	1.73
Rate, meters/second	8260

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:

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:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	None

65.5°C KI Test:

Minutes 6

Heat of: (e, f, g)

Combustion, cal/gm	1515		1525	
Explosion, cal/gm	1390	1454	1468	1520
Formation, cal/gm	337	345	366	

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, PA Special Report No. 238, 30 July 1925.

[42] See footnote 1, page 10.

(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. Brissaud 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).

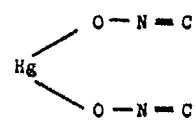
(l) O. E. Sheffield, Literature Survey on Mannitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TM1-16, 23 January 1952.

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

2	4	5	6
1352	24 64	85	6

Composition:

%	
C	8.4
N	9.8
O	11.2
Hg	70.6
C/H Ratio	



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

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber Shoe	Explodes

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature:

		°C
Seconds, 0.1 (no cap used)		263
1		239
5	Explodes	210
10		199
15		194
20		190

75°C International Heat Test:
% Loss in 48 Hrs 0.18

100°C Heat Test: Exploded in 16 hours
% Loss, 1st 48 Hrs
% Loss, 2nd 48 Hrs
Explosion in 100 Hrs

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.02

Volatility:

Molecular Weight: ($HgC_2N_2O_2$) 285

Oxygen Balance:

CO_2 %	-17
CO %	-5.5

Density: gm/cc Crystal 4.43

Melting Point: °C Decomposes

Freezing Point: °C

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	Explodes
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm
Black powder fuse 23.4

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % TNT: (a) 51

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

Mercury Fulminate

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: White to gray

Principal Uses: Detonators and ingredient of priming compositions

Method of Loading:

Loading Density: gm/cc

psi x 10^3	3	5	10	12	15	20
gm/cc	3.00	3.20	3.60	3.70	3.82	4.00

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M (wet)
Exudation	None

Stab Sensitivity:

Density gm/cc	Firing Point (inch-ounces) 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

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 1×10^{-4}

Mercury Fulminate

Initiating Efficiency; Grams Required to Give Complete Initiation of:

	Fulminate, gm
TNT	0.2[illegible]
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

Months	Recrystallized Lots				Uncrystallized Lots	
Storage	979	980	981	982	505.6-7/31	505.3-5/11
0	99.75	99.77	99.79	99.79	98.86	
4						98.7
6	99.38	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:

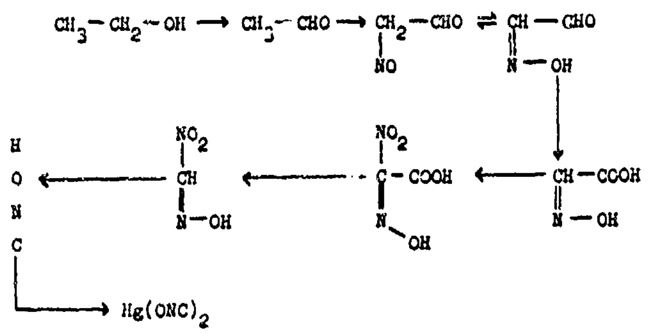
Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing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

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

°C	%
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis)



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

Origin:

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

Destruction by Chemical Decomposition:

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

References:[43]

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

(b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

[43]See footnote 1, page 10.

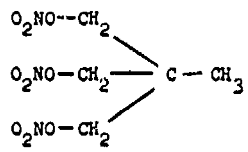
(c) Also see the following Picatinny Arsenal Technical Reports on Mercury Fulminate:

0	1	2	3	4	5	6	7	8	9
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							

 Metriol Trinitrate (MTN) Liquid (or Trimethylolethane Trinitrate)

Composition:

	%
C	23.5
H	3.5
N	16.6
O	56.4



C/H Ratio 0.150

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

Friction Pendulum Test:
Steel Shoe Explodes
Fiber Shoe

Rifle Bullet Impact Test: Trials
%
Explosions
Partials
Burned
Unaffected

Explosion Temperature: °C
Seconds, 0.1 (no cap used)
1
5 Ignites 235
10
15
20

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:
% Loss, 1st 48 Hrs 2.5
% Loss, 2nd 48 Hrs 1.8
Explosion in 100 Hrs None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.07

Volatility: 60°C, mg/cm²/hr 24

Molecular Weight: ($C_5H_9N_3O_9$) 255

Oxygen Balance:
CO_2 % -35
CO % -3

Density: gm/cc Liquid 1.47

Melting Point: °C -3

Freezing Point: °C

Boiling Point: °C

Refractive Index, n^{20}_{D}
n^{25}_{D} 1.4752
n^{30}_{D}

Vacuum Stability Test:
cc/40 Hrs, at
90°C
100°C cc/gm 1.9
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm 43.7

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT: (a) 136

Trauzl Test, % TNT: (b) 140

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

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: Oily, slightly turbid

Principal Uses: Ingredient of rocket and double base propellants

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Liquid
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	

Solubility in Water, gm/100 gm, at:

25°C	<0.015
60°C	<0.015

Heat of:

Combustion, cal/gm	2642

Hydrolysis, % Acid:

10 days at 22°C	0.018
5 days at 60°C	0.115

Metriol Trinitrate (MTN) Liquid

Preparation:

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

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

Metriol is nitrated by carefully mixing it with 3.5 parts of 65/35 HNO_3/H_2SO_4 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. H. 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.

[44] See footnote 1, page 10.

Composition:	%
Ammonium Nitrate	40
TNT	40
Aluminum	20
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	35
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	13
Sample Wt, mg	17
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 Ignites	435
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	
Flammability Index:	100
Hygroscopicity: %	
Volatility:	

Molecular Weight:		71
Oxygen Balance:		
CO_2 %		-38
CO %		-20
Density: gm/cc		1.62-1.68
Melting Point: °C		
Freezing Point: °C		
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		
120°C		2.1
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:	(a)	143
Trauzl Test, % TNT:	(b)	165
Plate Dent Test:	(c)	
Method		B
Condition		Pressed
Confined		No
Density, gm/cc		1.73
Brisance, % TNT		66
Detonation Rate:	(d)	
Confinement		None
Condition		Cast
Charge Diameter, in.		1.6
Density, gm/cc		1.68
Rate, meters/second		5820

Booster Sensitivity Test:	(e)
Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	1.46
Wax, gm	
Density, gm/cc	1.74

Heat of:	(f)
Combustion, cal/gm	3160
Explosion, cal/gm	1620
Gas Volume, cc/gm	
Formation, cal/gm	
Fusion, cal/gm	

Specific Heat: cal/gm/°C	
At -5°C	0.30
Density, gm/cc	1.74

Burning Rate:	
cm/sec	

Thermal Conductivity:	(b)
cal/sec/cm/°C	16.5×10^{-4}
Density, gm/cc	1.74

Coefficient of Expansion:	
Linear, %/°C	
Volume, %/°C	

Hardness, Mohs' Scale:	

Young's Modulus:	(b)
E', dynes/cm²	5.03×10^{10}
E, lb/inch²	0.73×10^{6}
Density, gm/cc	1.66

Compressive Strength: lb/inch² (b)	1910-2070
Density, gm/cc	1.68

Vapor Pressure:	
°C	mm Mercury

Decomposition Equation:	
Oxygen, atoms/sec (Z/sec)	
Heat, kilocalorie/mole (ΔH, kcal/mol)	
Temperature Range, °C	
Phase	

Armor Plate Impact Test:	(f)
60 mm Mortar Projectile:	
50% Inert, Velocity, ft/sec	828
Aluminum Fineness	
500-lb General Purpose Bombs:	
Plate Thickness, inches	
1	
1¼	
1½	
1¾	

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	

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	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

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

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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.

Minol-2

Origin:

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

Composition, %:	Minol-1	Minol-2	Minol-3
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.

[45] See footnote 1, page 10.

Composition: %		**Molecular Weight:**	40.6
Oxidizing agent (Ammonium Perchlorate)	35.0	**Oxygen Balance:**	
Aluminum, atomized	26.2	CO_2 %	-44
Cupric Oxide	----	CO %	-37
Magnesium, atomized	26.2	**Density:** gm/cc Pressed	2.0
Other ingredient (Tetryl)	9.7	**Melting Point:** °C	
Calcium Stearate	1.9	**Freezing Point:** °C	
Graphite, artificial	1.0	**Boiling Point:** °C	
C/H Ratio		**Refractive Index,** n°_{D}	
Impact Sensitivity, 2 Kg Wt:		n°_{D}	
Bureau of Mines Apparatus, cm	--	n°_{D}	
Sample Wt 20 mg		**Vacuum Stability Test:**	
Picatinny Arsenal Apparatus, in.	13	cc/40 Hrs, at	
Sample Wt, mg	22	90°C	----
Friction Pendulum Test:		100°C	0.47
Steel Shoe	Detonates	120°C	
Fiber Shoe	Unaffected	135°C	
Rifle Bullet Impact Test: Trials		150°C	
%		**200 Gram Bomb Sand Test:**	
Explosions		Sand, gm	10.6
Partials		**Sensitivity to Initiation:**	
Burned		Minimum Detonating Charge, gm	
Unaffected		Mercury Fulminate	----
Explosion Temperature:	°C	Lead Azide	0.20
Seconds, 0.1 (no cap used)	---	Tetryl	0.25
1	---	**Ballistic Mortar, % TNT:**	
5	285	**Trauzl Test, % TNT:**	
10		**Plate Dent Test:**	
15		Method	
20		Condition	
75°C International Heat Test:		Confined	
% Loss in 48 Hrs		Density, gm/cc	
Discoloration, fumes, odor	None	Brisance, % TNT	
100°C Heat Test:		**Detonation Rate:**	
% Loss, 1st 48 Hrs	0.10	Confinement	
% Loss, 2nd 48 Hrs	0.01	Condition	
Explosion in 100 Hrs	None	Charge Diameter, in.	
Flammability Index:		Density, gm/cc	
Hygroscopicity: %		Rate, meters/second	
Volatility:			

MOX-1

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Gray powder mixture
For TNT	
For Subject HE	**Principal Uses:** Small caliber antiaircraft projectiles
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Pressed
For TNT	
For Subject HE	
	Loading Density: gm/cc
	At 30,000 psi ~2.0
Fragment Velocity: ft/sec	**Storage:**
At 9 ft	
At 25½ ft	
Density, gm/cc	Method: Dry
Blast (Relative to TNT):	Hazard Class (Quantity-Distance): Class 9
Air:	Compatibility Group: Group I
Peak Pressure	Bureau of Explosives Classification Class A
Impulse	Exudation
Energy	
Air, Confined:	Heat of:
Impulse	Combustion, cal/gm: 4087
	Explosion, cal/gm: 2087
Under Water:	Gas volume, cc/gm: 212
Peak Pressure	Performance Tests:
Impulse	20 mm T215E1 Projectile:
Energy	NFOC Pressure Cube: 35
Underground:	APG Blast Cube: 40
Peak Pressure	Activation Energy:
Impulse	kcal/mol: 12.5
Energy	Temp, °C: 300 to 380
	Time to ignition, seconds: 1.78×10^{-4}

Composition:

%	
Oxidizing agent (Ammonium Perchlorate)	35.0
Aluminum, atomized	52.4
Cupric Oxide	----
Magnesium, atomized	----
Other ingredients*	9.7
Calcium Stearate	1.9
Graphite, artificial	1.0

*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	12
Sample Wt, mg	24

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	---
1	---
5	375
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs	
Discoloration, fumes, odor	None

100°C Heat Test:

% Loss, 1st 48 Hrs	0.27
% Loss, 2nd 48 Hrs	0.12
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: 42

Oxygen Balance:

CO_2 %	-49
CO %	-43

Density: gm/cc Pressed 2.0

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	----
100°C	0.21
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm	11.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.20

Ballistic Mortar, % TNT:

Trauzl 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

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):

	EW*	EV*
Air: Bare Charge:		
Peak Pressure	1.02	1.34
Impulse	1.08	1.41
Energy		
Density, gm/cc		1.96
Air, Confined:		
Impulse		
Cased Charge in Air:**		
Peak Pressure	1.09	1.44
Impulse	1.16	1.53
Energy	----	----
Density, gm/cc		1.98
Underground:		
Peak Pressure		
Impulse		
Energy		

*EW, equivalent weight as compared to TNT;
EV, equivalent volume as compared to TNT.

**Strong paper-base phenolic case.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Gray

Principal Uses: HE filler for small caliber projectiles

Method of Loading: Pressed

Loading Density: gm/cc 2.0

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Bureau of Explosives Class A	
Exudation	None

Heat of:

Combustion, cal/gm	4484
Explosion, cal/gm	1472
Gas volume, cc/gm	221

Performance Tests:
20 mm T215E1 Projectile:

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}

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

Simulated Altitude, Feet	One-Inch Column Confined m/s	One-Inch Column Unconfined m/s	Two-Inch Column Confined m/s	Two-Inch Column Unconfined m/s
Ground	Charge would not propagate detonation.		4730	Charge would not propagate detonation.
30,000			4530(3)	
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)

Explosive	Charge Diameter, Inches	Simulated Altitude, Feet: Ground m/s	30,000 m/s	60,000 m/s	90,000 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.

MOX-3B

Composition:

	%
Oxidizing agent (Potassium Nitrate)	18
Aluminum, atomized	50
Cupric Oxide	--
Magnesium, atomized	--
Other ingredients*	32
Calcium Stearate**	2.0
Graphite, artificial**	1.0

*29.1% RDX, 0.9% wax, and 2.0% TNT.
**Per cent added.

Molecular Weight: 45.6

Oxygen Balance:

CO_2 %	-52
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	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	17
Sample Wt, mg	24

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	0.57
120°C	
135°C	
150°C	

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

200 Gram Bomb Sand Test:

Sand, gm 33.2

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	---
1	---
5	540
10	
15	
20	

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.15

Ballistic Mortar, % TNT:

Trauzl 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	0.35
% Loss, 2nd 48 Hrs	0.13
Explosion in 100 Hrs	None

Detonation Rate:

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

Flammability Index:

Hygroscopicity: %

Volatility:

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: Gray powder mixture

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 Class A

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

Temp, °C

Time to ignition, seconds

Values not included due to erratic ignition under conditions of test.

Composition:

%	
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.

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	78
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	18
Sample Wt, mg	26

Friction Pendulum Test:

Steel Shoe	Sparks
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	---
1	---
5	610
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs
Discoloration, fumes, odor None

100°C Heat Test:

% Loss, 1st 48 Hrs	0.22
% Loss, 2nd 48 Hrs	0.12
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: 48

Oxygen Balance:

CO_2 %	-53
CO %	-43

Density: gm/cc Pressed 2.0

Melting Point: °C

Freezing Point: °C

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	0.67
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 33.6

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.15

Ballistic Mortar, % TNT:

Trauzl 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

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 powder mixture
	Principal Uses: Small caliber antiaircraft projectiles
	Method of Loading: Pressed
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	**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 4392 Explosion, cal/gm 709 Gas volume, cc/gm 208 Performance Tests: 20 mm T215E1 Projectile: NFOC Pressure Cube 43 APG Blast Cube 53 Aviation Energy: kcal/mol Temp, °C Time to ignition, seconds Values not included due to erratic ignition under conditions of test.

MOX-6B

Composition:	%
Oxidizing agent	----
Aluminum, atomized	49.2
Cupric Oxide	19.7
Magnesium, atomized	----
Other ingredients*	29.6
Calcium Stearate	----
Graphite, artificial	1.5
*28.7% RDX coated, 0.9% wax.	
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	78
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	19
Sample Wt, mg	27
Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
Rifle Bullet Impact Test:	Trials
	%
Explosions	
Partials	
Burned	
Unaffected	
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	---
1	---
5	510
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	0.02/10 gm
Discoloration, fumes, odor	None
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: %	
30°C, 90% RH, two weeks	0.79
Volatility:	

Molecular Weight:	43
Oxygen Balance:	
CO_2 %	-50
CO %	-42
Density: gm/cc	
Melting Point: °C	
Freezing Point: °C	
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	0.43
120°C	
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	10.8
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.20
Tetryl	0.16
Ballistic Mortar, % TNT:	
Trauzl 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	

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:	Gray powder mixture
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 Class A

Heat of:

Combustion, cal/gm	4293
Explosion, cal/gm	750
Gas volume, cc/gm	204

Activation Energy:

kcal/mol Temp, °C Time to ignition, seconds	Values not included due to erratic ignition under conditions of test.

Preparation:

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

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

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer's 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about 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.

References:[46]

(a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task 1, National Fireworks Ordnance Corporation, First Yearly Summary, August 1950 to August 1951.

(b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, December 1952.

(c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.

(d) A. O. Mirarchi, Properties of Explosives: MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.

(e) A. T. Wilson, Development of MOX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.

(f) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.

(g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-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.

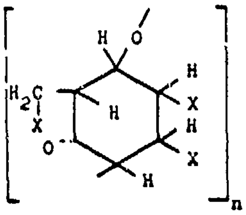
[46] See footnote 1, page 10.

Nitrocellulose, 12.6% N (NC)

Composition:

	%
C	26.46
H	2.78
N	12.60
O	58.16

$X = ONO_2$



C/H Ratio 0.23

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	8
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	3
Sample Wt, mg	5

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)		°C
1		
5	Decomposes	170
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

Flammability Index:

Hygroscopicity: % 30°C, 90% RH — 3

Volatility: 60°C, $mg/cm^2/hr$ — 0.0

Molecular Weight: $(272.39)_n$

Oxygen Balance:

CO_2 %	-35
CO %	0.6

Density: gm/cc

Melting Point: °C — Decomposes

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_D^{20}

n_D^{25}

n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at

90°C		0.17
100°C		1.0
120°C	16 hours	11.+
135°C		
150°C		

200 Gram Bomb Sand Test:

Sand, gm — 45.0

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.10
Tetryl	

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement

Condition

Charge Diameter, in.

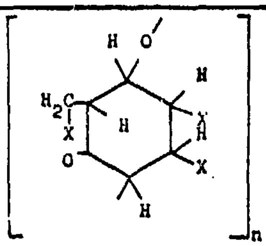
Density, gm/cc

Rate, meters/second

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

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	230
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.3
% Loss, 2nd 48 Hrs	0.0
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH ~ 2

Volatility: 60°C, $mg/cm^2/hr$ 0.0

Molecular Weight: $(286.34)_n$

Oxygen Balance:

CO_2 %	-29
CO %	4.7

Density: gm/cc

Melting Point: °C Decomposes

Freezing Point: °C

Boiling Point: °C

Refractive Index, n^D_{20}

n^D_{25}

n^D_{30}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	0.42
100°C	1.5
120°C	11.+
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm 49.0

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.10
Tetryl	

Ballistic Mortar, % TNT: 125

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

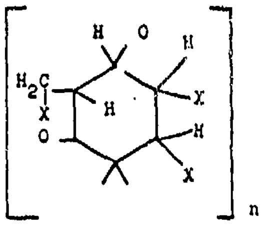
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	1.20
Rate, meters/second	7300

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 of Mines Apparatus, cm	8
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	3
Sample Wt, mg	5

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	
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

Flammability Index:

Hygroscopicity: % 30°C, 90% RH ~ 1

Volatility: 60°C, $mg/cm^2/hr$ 0.0

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_D^{20}

n_D^{25}

n_D^{30}

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		

200 Gram Bomb Sand Test:

Sand, gm 52.3

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.10
Tetryl	

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement

Condition

Charge Diameter, i

Density, gm/cc

Rate, meters/second

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: White

Principal Uses: Pyroxylin (12% N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Wet (8% to 30% water)
Hazard Class (Quantity-Distance)	Class 12
Compatibility Group	Group K (wet)
Exudation	None

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

Vapor Pressure:

°C	mm Mercury
25	0.00
60	0.00

Nitrocellulose (NC)

Solubility in Water, gm/100 gm, at:	12.6% N	13.45% N	14.0% N
25°C	Insoluble	Insoluble	Insoluble
60°C	Insoluble	Insoluble	Insoluble
Solubility, gm/100 gm, 25°C, in:			
Ether	Insoluble	Insoluble	Insoluble
Alcohol	Very slightly soluble	Practically insoluble	Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + %)
Acetone	Soluble	Soluble	Soluble
240-Hour Hydrolysis Test, % Nitric Acid	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:

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:

[47] See footnote 1, page 10.

Nitrocellulose (NC)

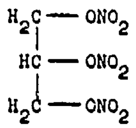
0	1	2	3	4	5	6	7	8	9
10	41	72	13	4	125	86	167	8	19
390	101	332	33	24	475	576	327	198	29
420	231	402	43	114	485	586	407	208	69
660	351	422	133	174	495	796	717	278	169
730	551	542	233	194	555	916	787	388	279
960	831	572	253	334	705	1016	987	408	499
1020	851	652	273	374	965	1026	1187	588	659
1100	971	662	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	952	773	894	1205	1276	1327	808	779
1240	1151	1012	793	1024	1265	1306	1407	838	809
1300	1201	1032	963	1054	1275	1316	1427	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)

Composition:

%	
C	15.9
H	2.2
N	18.5
O	63.4

C/H Ratio 0.109



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	

Friction Pendulum Test:

Steel Shoe	Explodes
Fiber Shoe	

Rifle Bullet Impact Test: Trials

	%
Explosions	100
Partials	0
Burned	0
Unaffected	0

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		
1		
5	Explodes	222
10		
15		
20		

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	3.6
% Loss, 2nd 48 Hrs	3.5
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.06

Volatility: 60°C, $mg/cm^2/hr$ 0.11

Molecular Weight: ($C_3H_5N_3O_9$) 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

Boiling Point: °C Decomposes 145

Refractive Index,

n_{20}^{D}	1.4732
n_{25}^{D}	1.4713
n_{30}^{D}	

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		

200 Gram Bomb Sand Test:
Sand, gm Liquid method 51.5

Sensitivity to Initiation:
Minimum Detonating Charge, gm
- Mercury Fulminate
- Lead Azide
- Tetryl

Ballistic Mortar, % TNT: (a) 140

Trauzl Test, % TNT: (b) 181

Plate Dent Test:
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

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

Nitroglycerin (Liquid)

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:

Combustion, cal/gm	1616
Explosion, cal/gm	1600
Gas Volume, cc/gm	715
Formation, cal/gm	400
Fusion, cal/gm	
Detonation, cal/gm	1486

Specific Heat: cal/gm/°C

Liquid	0.356
Solid	0.315

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	°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

Decomposition Equation:

Oxygen, atoms/sec (Z/sec)	$10^{17.3}$	$10^{19.2}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	41.4	45.0
Temperature Range, °C	90-135	125-150
Phase	Liquid	Liquid

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

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

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: Colorless

Principal Uses: Propellant ingredient, demolition explosive ingredient, grenade burster ingredient

Method of Loading:

Loading Density: gm/cc

Storage:

Method: With acetone or other desensitizer, generally not stored

Hazard Class (Quantity-Distance): Class 9

Compatibility Group

Exudation

Heat of Transition, cal/gm:

Transition:

Liquid → labile	5.2
Labile → stable	28.0
Liquid → stable	33.2

Hydrolysis, % Acid:

10 days at 22°C	< 0.002
5 days at 60°C	0.005

82.1°C KI Test:

Minutes	10+

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)

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

Fragmentation Test:

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

Nitroglycerin	22
Tetranitromethane	17

Minimum Propagating Diameter: (d)

% Dimethylphthalate in NG	Min. Propagating Diameter, inches	Maximum Diameter for 2 Failures in 2 Trials, inches
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:

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

Nitroglycerin (Liquid)

Carbon Disulfide	
°C	%
Ambient	1

gm/100 gm (%), at 25°C in	
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 DNT
Ethyl nitrate	Chloroform
Nitroglycol	Ethyl chloride
Tetranitrodiglycerine	Ethyl bromide
Acetic acid	Tetrachloroethylene
Benzene	Dichloroethylene
Toluene	Trimethyleneglycol Dinitrate

Solubility in NG, of:

Alcohol		DNT		TNT		Water	
°C	%	°C	%	°C	%	°C	%
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 5. 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.

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 ($Na_2S \cdot 9H_2O$). 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-Sprengstoffw, 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.

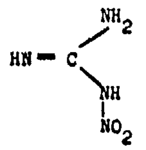
(e) Also see the following Picatinny Arsenal Technical Reports on Nitroglycerin:

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								

[48]See footnote 1, page 10.

Composition:

%	
C	11.5
H	3.9
N	53.8
O	30.8



C/H Ratio 0.038

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	47
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	26
Sample Wt, mg	7
Friction Pendulum Test:	(e)
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
Rifle Bullet Impact Test: 5 Trials (e)	%
Explosions	0
Partials	0
Burned	0
Unaffected	100
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	
1	
5 Decomposes	275
10	
15	
20	
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
Flammability Index:	
Hygroscopicity: % 30°C, 90% RH	None
Volatility:	None

Molecular Weight: ($CH_4N_4O_2$)	104
Oxygen Balance:	
CO_2 %	-31
CO %	-15.4
Density: gm/cc Crystal	1.72
Melting Point: °C	232
Freezing Point: °C	
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	0.37
120°C	0.44
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	36.0
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.10
Ballistic Mortar, % TNT: (a)	104
Trauzl Test, % TNT: (b)	101
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

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: 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	

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

	°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*

* gm/100 cc solution

Booster Sensitivity Test: (d)

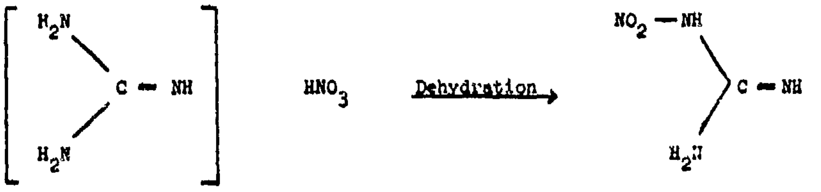
Condition	Pressed
Tetryl, gm	100
Wax, in. for 50% Detonation	0.67
Density, gm/cc	1.41

Heat of:

Combustion, cal/gm	1995
Explosion, cal/gm	721
Gas Volume, cc/gm	1077
Formation, cal/gm	227

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. Eyster, 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 Tetryl 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.

[49] See footnote 1, page 10.

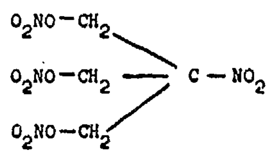
(f) Also see the following Picatinny Arsenal Technical Reports on Nitroguanidine:

0	1	2	3	6	7	8	9
1490	1391	1282	1183	1336	907	758	1439
	2181	1392	1423		2177		1749
	2201	2142	2193				

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

Composition:

%	
C	16.8
H	2.1
N	19.6
O	61.5



C/H Ratio 0.126

Impact Sensitivity, 2 Kg Wt:
- Bureau of Mines Apparatus, cm: 25
- Sample Wt 20 mg
- Picatinny Arsenal Apparatus, in.
- 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	Ignites	185
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

Flammability Index:

Hygroscopicity: %

Volatility:
- 25°C, mg/cm²/24 hrs: 0.127×10^{-3}

Molecular Weight: ($C_4H_6N_4O_{11}$) 286

Oxygen Balance:
- CO_2 %: 0.0
- CO %: 22

Density: gm/cc 20°C: 1.64

Melting Point: °C

Freezing Point: °C: -39

Boiling Point: °C

Refractive Index,
- n_D [illegible]
- n_D [illegible]: 1.4896
- n_D [illegible]: 1.4874

Vacuum Stability Test:
- cc/40 Hrs, at
- 90°C
- 100°C
- 120°C
- 135°C
- 150°C

200 Gram Bomb Sand Test:
- Sand, gm: 0.2 gm sample absorbed by 0.2 gm of kieselguhr: 28

Sensitivity to Initiation:
- Minimum Detonating Charge, gm
  - Mercury Fulminate
  - Lead Azide
  - Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:
- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

Detonation Rate:

Confinement	Glass (1 mm wall)
Condition	Liquid
Charge Diameter, in.	0.39
Density, gm/cc	1.64
Rate, meters/second	7860

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 oil

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:

Minutes 2

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

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 Trimethylolnitromethane Trinitrate, Nitroisobutanetriol Trinitrate, Nitroisobutylglycerin Trinitrate and incorrectly but widely used Nitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 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. Hass, Ind Eng Chem 32, 427-9 (1940); CA 34, 3235 (1940).

(f) A. Stettbacher, Z ges Schiess Sprengstoffw 37, 62-4 (1942); CA 38, 255 (1944).

[50] See footnote 1, page 10.

Nitrostarch Demolition Explosive (NSX)

Composition:	%	
Nitrostarch (12.50% N)	49	
Barium Nitrate	40	
Mononitronaphthalene	7	
Paranitroaniline	3	
Oil	1	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	21	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	8	
Sample Wt, mg		
Friction Pendulum Test:		
Steel Shoe	Crackles, snaps	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	10 Trials	8 Trials*
	%	%
Explosions	90	0
Partials	0	13
Burned	0	0
Unaffected	10	87
*Packed in paper		
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	--	
1	--	
5 Decomposes	195	
10		
15		
20		
75°C International Heat Test:		
% Loss in 48 Hrs	0.2	
100°C Heat Test:		
% Loss, 1st 48 Hrs	0.3	
% Loss, 2nd 48 Hrs	0.3	
Explosion in 100 Hrs	None	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH	2.1	
Volatility:		

Molecular Weight:	325
Oxygen Balance:	
CO_2 %	-19
CO %	8
Density: gm/cc	
Melting Point: °C	
Freezing Point: °C	
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	11+
120°C	
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	39.5
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.26
Lead Azide	--
Tetryl	--
Ballistic Mortar, % TNT: (a)	96
Trauzl 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	

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:

Principal Uses: Demolition, bursting charges, and priming compositions

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

120°C Heat Test:

	Minutes
Salmon Pink	70
Red Fumes	255
Explodes	256

Nitrostarch Demolition Explosive (NSX)

Preparation: (b)

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

$$2C_6H_{10}O_5 + 6HNO_3 \rightarrow C_{12}H_{14}O_4(ONO_2)_6 + 6H_2O$$

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 Braconnot, 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:

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

[51]See footnote 1, page 10.

Octol, 70/30

Composition: %	**Molecular Weight:** 265
HMX 70	**Oxygen Balance:**
TNT 30	CO_2 % -38
	CO % -7.5
C/H Ratio	**Density:** gm/cc Cast 1.80
	Melting Point: °C
	Freezing Point: °C
	Boiling Point: °C

Impact Sensitivity, 2 Kg Wt:	**Refractive Index,** n_{D}
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in. 18	
Sample Wt, mg 26	

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Vacuum Stability Test:

cc/40 Hrs, at

90°C	----
100°C	----
120°C	0.37
135°C	
150°C	

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

200 Gram Bomb Sand Test:

Sand, gm Exploratory 58.4

Explosion Temperature: °C

Seconds		°C
0.1 (no cap used)		---
1		---
5	Flames erratically	335
10		
15		
20		

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	----
Lead Azide	0.30
Tetryl	----

Ballistic Mortar, % TNT: 115

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

Flammability Index:

Hygroscopicity: %

Volatility:

Detonation Rate:

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.80
Rate, meters/second	8377

Booster Sensitivity Test:	
Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	
Heat of:	
Combustion, cal/gm	2722
Explosion, cal/gm	1074
Gas Volume, cc/gm	847
Formation, cal/gm	----
Fusion, cal/gm	
Specific Heat: cal/gm/°C	
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	1510 See below
Vapor Pressure:	
°C mm Mercury	
Compressive Strength: lb/inch²	*
Average (10 tests)	1510
High	1740
Low	1330

Decomposition Equation:	
Oxygen, atoms/sec (Z/sec)	
Heat, kilocalorie/mole (ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	
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.

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: Buff

Principal Uses: HE projectile and bomb filler

Method of Loading: Cast

Loading Density: gm/cc 1.80

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

Work to Produce Rupture: ft-lb/inch^3 *

Average (10 tests)	1.55
High	1.87
Low	1.10

Efflux Viscosity, Saybolt Seconds: 5.9

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

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

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

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

Average Fragment Velocities at Various Altitudes* (g)

Explosive	Charge Diameter, Inches	Ground m/s	30,000 m/s	60,000 m/s	90,000 m/s
70/30, RDX/TNT	1	3415	3672	3666	3685
	2	4647	5192	6236	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".

Octol, 70/30

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, gm/cc	1.72

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

Pit Fragmentation Test:

105 mm M1 HE Projectile:

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

Octol, 75/25

Composition:			
%			
HMX	75		
TNT	25		
C/H Ratio			
Impact Sensitivity, 2 Kg Wt:			
Bureau of Mines Apparatus, cm	--		
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.	17		
Sample Wt, mg	25		
Friction Pendulum Test:			
Steel Shoe	Unaffected		
Fiber Shoe	Unaffected		
Rifle Bullet Impact Test: 10 Trials %	3/16" Steel	1/8" Al	
Explosions	70	70	
Partials	--	--	
Burned	--	--	
Unaffected	30	30	
Explosion Temperature:	°C		
Seconds, 0.1 (no cap used)	---		
1	---		
5 Flames erratically	350		
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			
Flammability Index:			
Hygroscopicity: %			
Volatility:			

Molecular Weight:		276
Oxygen Balance:		
CO_2 %		-35
CO %		-6.3
Density: gm/cc	Cast	1.81
Melting Point: °C		
Freezing Point: °C		
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		----
120°C		0.39
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm	Exploratory	62.1
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		----
Lead Azide		0.30
Tetryl		----
Ballistic Mortar, % TNT:		116
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.81
Rate, meters/second		8643

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

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.

Specific Heat: cal/gm/°C **

-79°C	0.200
-80° to +80°C	0.240
33° to 74°C	0.245
90° to 150°C	0.323

**Determined for 76.9% HMX, 23.1% TNT.

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 1340 See below

Vapor Pressure:
°C mm Mercury

Compressive Strength: lb/inch² ***

Average (10 tests)	1340
High	1560
Low	1040

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

Ultimate Deformation: %

Average (10 tests)	2.43
High	2.89
Low	2.04

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

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

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: Buff

Principal Uses: HE projectile and bomb filler

Method of Loading: Cast

Loading Density: gm/cc 1.81

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

Work to Produce Rupture: ft-lb/inch^3 *

Average (10 tests)	1.31
High	1.57
Low	1.07

Efflux Viscosity, Saybolt Seconds: 9.0

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

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 XL-076B, 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

Preparation:

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

[52]See footnote 1, page 10.

Composition:

%	
RDX	90
Polystyrene (unmodified)	8.5
Dioctylphthalate	1.5

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

	Unpressed
Bureau of Mines Apparatus, cm	28
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	15
Sample Wt, mg	20

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 10 Trials *

	%
Explosions	10
Partials	90
Burned	0
Unaffected	0

Explosion Temperature:

Seconds		°C
0.1 (no cap used)		---
1		---
5	Smokes	275
10		
15		
20		

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

* Test procedure described in PATR No. 2247, May 1956.

Molecular Weight: 245

Oxygen Balance:

CO_2 %	-62
CO %	-18

Density: gm/cc

Unpressed	0.81
Pellet pressed at 30,000 psi	1.62

Melting Point: °C

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	----
100°C	----
120°C	0.41
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl 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

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:

Combustion, cal/gm	3027
Explosion, cal/gm	983
Gas Volume, cc/gm	
Formation, cal/gm	
Fusion, cal/gm	

Specific Heat: cal/gm/°C

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/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²	2403	2149
Percent	8.9	13.1

Vapor Pressure:
°C mm Mercury

Young's Modulus: * (a)

	Temperature	
	Ambient	95°C
E, lb/inch² (avg of 5)	39,953	34,831
Density, gm/cc	1.60	1.57

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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

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: White

Principal Uses: High mechanical strength explosive

Method of Loading: Pressed

Loading Density: gm/cc Pressed, psi x 10^3

0	10	20	30
1.10	1.49	1.59	1.62

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:

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

*Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.

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

Pellets	Gap (Distance From Base of Cap to Pellet), Inches 0.250	0.300	0.350	0.400	0.450	0.500	0.750
PB-RDX with Pellet Density 1.55 gm/cc							
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
PB-RDX with Pellet Density 1.60 gm/cc							
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
98/2 RDX/Stearic Acid With Pellet Density 1.63 gm/cc							
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 M1 Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

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

PB-RDX

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 H_2O (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 dioctyphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

Commission, Report No. 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. Pascazio, The Suitability of a Bare PBX Booster Pellet in the 2.75 Inch M1 HEAT Rocket Head, PATR No. 2271, November 1955.

(c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded RDX, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-T-16 Series A (PAC 1081), 5 March 1953.

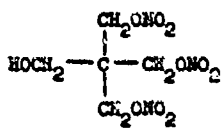
(d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307A1 (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

[53] See footnote 1, page 10.

Pentaerythritol Trinitrate (PETRIN)

Composition:

	%
C	22.1
H	3.3
N	15.5
O	59.1



C/H Ratio 0.141

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

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	
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

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: ($C_5H_9N_3O_{10}$) 271

Oxygen Balance:

CO_2 %	-27
CO %	3

Density: gm/cc 1.54

Melting Point: °C 26 to 28

Freezing Point: °C

Boiling Point: °C 4 mm Hg Decomposes 130

Refractive Index, n_D^{20}

n_D^{25}

n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	----
100°C	2.54 to 5.69
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate

Lead Azide

Tetryl

Ballistic Mortar, % TNT:

Trauzl 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

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

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

Absolute Viscosity, poises:

Temp, 17°C	14.3
23°C	4.8
28°C	3.0
38°C	1.2

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses: Explosive, propellant or igniter ingredient

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	None

PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.

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.

Heat of:

Explosion, cal/gm 1204

Preparation:

$$C(CH_2OH)_4 + 3HNO_3 \xrightarrow{H_2SO_4} OHCH_2C(CH_2NO_3)_3 + 3H_2O$$

pentaerythritol	nitric acid	sulfuric acid	pentaerythritol trinitrate	water
MW 136	MW 63	MW 98	MW 271	MW 18

The earliest procedure used for the manufacture of PETRIN was that developed at Alleghany Ballistics Laboratory. In this process, called the "A process," 80% HNO_3 and the solid pentaerythritol were charged to the reactor and 80% H_2SO_4 was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammonium carbonate, after which the 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 NO_2 groups were patented for use as explosives, propellants or ignition materials in 1936 (German Patents 638,432 and 638,433; CA 31, 1212 (1937)).

A process in which pentaerythritol monoacetate was converted to pentaerythritol trinitrate monoacetate, which was then saponified under carefully controlled conditions to PETRIN, was reported in 1954 (N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 76, 1304). PETRIN was also prepared by the nitration of pentaerythritol with a mixture of 80% HNO_3 and 80% H_2SO_4 in 1955 (A. T. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

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.

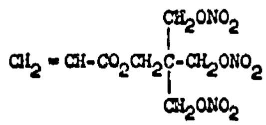
(c) R. H. Pierson, An Infrared Spectrophotometric Method for Determination of Acetone Content of Pentaerythritoltrinitrate, U.S. Naval Ordnance Test Station Report NOTS 1877, NAVORD Report No. 5649, 3 February 1958.

[54]See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate)
(Trinitroxypentaerythritol Acrylate)

Composition:

%	
C	29.5
H	3.4
N	12.9
O	54.2



C/H Ratio 0.239

Impact Sensitivity, 2 Kg Wt:
Bureau of Mines Apparatus, cm
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
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
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

Flammability Index:

Hygroscopicity: % Nil

Volatility:

Molecular Weight: ($C_8H_{11}N_3O_{11}$) (Monomer) 325

Oxygen Balance:
CO_2 % -54
CO % -12

Density: gm/cc

Melting Point: °C 78 to 79

Freezing Point: °C

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
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl 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

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-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
	Principal Uses: Ingredient of composite rocket propellants
	Method of Loading:
	Loading Density: gm/cc
Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc	**Storage:** Method: Dry at temperatures below melting point 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: Combustion, cal/gm: 2923 Explosion, cal/gm: 791

Preparation: (a)

$HOCH_2C(CH_2NO_3)_3$	+	$CH_2 = CHCOCl$	+	$C_6H_5N(CH_3)_2$
pentaerythritol trinitrate (PETRIN) MW 271		acrylyl chloride MW 90.5		dimethyl aniline MW 121

$\rightarrow (O_2NOCH_2)_3CCH_2OC(O)CH = CH_2 + C_6H_5N(CH_3)_2HCl$

pentaerythritol trinitrate monoacrylate (PETRIN acrylate) MW 325 — dimethylaniline hydrochloride

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.

[55] See footnote 1, page 10.

Pentolite, 50/50; 10/90

Composition:

%		
PETN	50	10
TNT	50	90

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

	50/50	10/90
Bureau of Mines Apparatus, cm	34	65
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	12	14
Sample Wt, mg	15	18

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 25 Trials, 50/50

	%
Explosions	72
Partials	20
Burned	0
Unaffected	8

Explosion Temperature: °C, 50/50

Seconds, 0.1 (no cap used)		290
1		266
5	Decomposes	220
10		204
15		197
20		>190

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

	50/50
% Loss, 1st 48 Hrs	0.0
% Loss, 2nd 48 Hrs	0.2
Explosion in 100 Hrs	None

Flammability Index: Will not continue to burn

Hygroscopicity: %

	50/50	10/90
30°C, 90% RH	None	None

Volatility:

Molecular Weight:

	50/50	10/90
Molecular Weight	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		
Boiling Point: °C		

Refractive Index, n_D^{20}
n_D^{25}
n_D^{30}

Vacuum Stability Test:

cc/40 Hrs, at	50/50	10/90
90°C		
100°C	3.0	3.0
120°C	11+	11+
135°C	--	--
150°C	--	--

200 Gram Bomb Sand Test:

Sand, gm	55.6	49.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm	50/50
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
Condition	Cast
Confined	No
Density, gm/cc	1.66
Brisance, % TNT	121

Detonation Rate:

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.66
Rate, meters/second	7465

Pentolite, 50/50; 10/90

Booster Sensitivity Test: (d)

		50/50
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

Heat of:

Combustion, cal/gm	
Explosion, cal/gm	1220
Gas Volume, cc/gm	
Formation, cal/gm	
Fusion, cal/gm	

Specific Heat: cal/gm/°C

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	2000-2200
Density, gm/cc	1.68

Vapor Pressure:
°C mm Mercury

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

Armor Plate Impact Test: 50/50

60 mm Mortar Projectile:	
50% Inert, Velocity, ft/sec	170
Aluminum Fineness	

500-lb General Purpose Bombs:

Plate Thickness, inches

1
1¼
1½
1¾

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

Pentolite, 50/50; 10/90

Fragmentation Test: 50/50

90 mm HE, M71 Projectile, Lot WC-91:

	50/50
Density, gm/cc	1.65
Charge Wt, lb	[illegible]

Total No. of Fragments:

For TNT	703
For Subject HE	968

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.65
Charge Wt, lb	0.872

Total No. of Fragments:

For TNT	514
For Subject HE	650

Fragment Velocity: ft/sec

At 9 ft	2810
At 25½ ft	2580
Density, gm/cc	1.66

Blast (Relative to TNT): (e)

Air:

Peak Pressure	105
Impulse	107
Energy	--

Air, Confined:
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	25.3

Shaped Charge Effectiveness, TNT = 100:

	50/50	10/90	50/50	25/75
	Glass Cones(f)		Steel Cones (g)	
Hole Volume	157	105	149	119
Hole Depth	116	116	131	119

Color: Yellow-white

Principal Uses: Shaped charges, bursting charges, demolition blocks

Method of Loading: Cast

Loading Density: gm/cc

50/50	10/90
1.65	1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium or nickel are not affected. Zinc plated steel is only slightly affected.

Wet: Stainless steel, aluminum and mild steel coated with acid-proof black paint are not affected. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with copper, cadmium, zinc or nickel are slightly affected.

Effect of Temperature on Rate of Detonation: (h)

	50/50	
16 hrs at, °C	-54	21
Density, gm/cc	1.67	1.66
Rate, m/sec	7470	7440

Pentolite, 50/50; 10/90

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 Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

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

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract 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 1956.

(i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

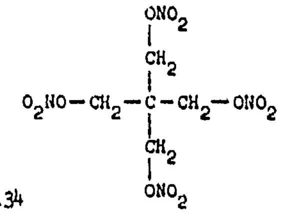
0	1	2	3	4	5	6	7	8
1360	1291	1212	1133	1284	1325	1436	1477	1388
1420	1451	1262	1193	2004		1466	1677	1598
1570	1651	1372	1213			1796	1737	1668
			1363					1838

[56] See footnote 1, page 10.

PETN (Pentaerythritol Tetranitrate)

Composition:

	%
C	19.0
H	2.5
N	17.7
O	60.8
C/H Ratio	0.134



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	17
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	6
Sample Wt, mg	16

Friction Pendulum Test:

Steel Shoe	Crackles
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: 5 Trials *

	%
Explosions	100
Partials	0
Burned	0
Unaffected	0

*4.86% moisture in samples

Explosion Temperature: °C

	°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

Molecular Weight: ($C_5H_8N_4O_{12}$) 316

Oxygen Balance:

CO_2 %	-10
CO %	15

Density: gm/cc Crystal 1.77

Melting Point: °C 141

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_{20}^{D}

n_{25}^{D}

n_{30}^{D}

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

Trauzl 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

PETN (Pentaerythritol Tetranitrate)

Booster Sensitivity Test:	(c)
Condition	Pressed
Tetryl, gm	5
Wax, in. for 50% Detonation	
Wax, gm	3
Density, gm/cc	1.6
Heat of:	
Combustion, cal/gm	1960
Explosion, cal/gm	1385
Gas Volume, cc/gm	790
Formation, cal/gm	383
Fusion, cal/gm	
Specific Heat: cal/gm/°C	(d)
Room Temperature	0.26
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°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	

Decomposition Equation:	(e)	(e)	(f)
Oxygen, atoms/sec (Z/sec)	$10^{19.8}$	$10^{20.6}$	$10^{23.1}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	47.0	50.9	52.3
Temperature Range, °C	161-233	108-120	137-157
Phase	Liquid	Solid	At melting point

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

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

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

Fragment Velocity: ft/sec
At 9 ft
At 25½ ft
Density, gm/cc

Blast (Relative to TNT):

Air:
Peak Pressure
Impulse
Energy

Air, Confined:
Impulse

Under Water:
Peak Pressure
Impulse
Energy

Underground:
Peak Pressure
Impulse
Energy

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses:
Class A - Detonating fuse and boosters
Class B - Priming compositions

Method of Loading:

Loading Density: gm/cc

psi x 10^3	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): (i)

Dynes/cm^2 x 10^{-10}	4.60
Density, gm/cc	1.77

PETN (Pentaerythritol Tetranitrate)

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 very 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

°C	%
0	0.070
20	0.195
40	0.415
60	1.205

Acetone

°C	%
0	14.37
20	24.95
40	30.56
60	42.68

Benzene

°C	%
0	0.150
20	0.450
40	1.160
80	7.900

Toluene

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

Methyl acetate

°C	%
20	13
30	17
40	22
50	31

Ether

°C	%
0	0.200
20	0.340
34.7	0.450

β-Ethoxy-ethyl-acetate

°C	%
20	1.5
30	4.1
40	7.6
50	11.2
60	14.2

Chlorobenzene

°C	%
20	0.35
30	2.8
40	6.1
50	9.2
60	12.2

Ethylenedichloride

°C	%
10	0.9
30	1.5
50	2.6

Methanol

°C	%
20	0.46
40	1.15
60	2.6

Tetrachloroethane

°C	%
20	0.18
30	0.27
40	0.40
50	0.58

Carbon tetrachloride

°C	%
20	0.096
30	0.103
40	0.118
50	0.121

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

Eutetic of the system PETN-TNT is about 13% PETN and 87% TNT at 76°C.

Preparation:

(Nitroglycerin and Nitroglycerin Explosives, Naoum)

$8HCHO + CH_3CHO + Ca(OH)_2 \longrightarrow 2C(CH_2OH)_4 + Ca(HCOO)_2 \quad C(CH_2OH)_4 + 4HNO_3 \longrightarrow C(CH_2ONO_2)_4 + 4H_2O$

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 pentaery-thritol, melting point 235°-240°C are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good agitation. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent 81,664 (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw 11, 1[illegible]; 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 ($Na_2S \cdot 9H_2O$) 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.

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 - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

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

(d) International Critical Tables.

(e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.

(f) A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglycerin, Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).

(g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(h) Various sources in the open literature.

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

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

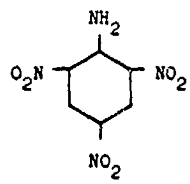
0	1	2	3	4	5	6	7	8	9
760	1041	772	843	904	1305	1246	407	318	1379
1170	1311	922	863	1274	1325	1276	527	838	1429
1260	1381	1182	1063	1284	1445	1316	857	1238	1489
1290	1451	1192	1133	1414	1705	1376	1247	1318	1559
1300	1561	1212	1253		1885	1446	1517	1388	2179
1320	1611	1262	1343		2125	1456	1617	1568	
1360	1651	1342	1493			1466	1737	1598	
1380		1352	1533			1556	1797	1838	
1390		1372				1796		2178	
1430		1452							
1450									
1570									

[57] See footnote 1, page 10.

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

Composition:

%	
C	31.5
H	1.8
N	24.5
O	42.2



C/H Ratio 0.500

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	23
Sample Wt, mg	20
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	
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	
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight: ($C_6H_4N_4O_6$)		228
Oxygen Balance.		
CO_2 %		-56
CO %		-14
Density: gm/cc	Crystal	1.76
Melting Point: °C		189 to 190
Freezing Point: °C		
Boiling Point: °C		Decomposes before boiling point
Refractive Index, n_D^{20}		
n_D^{25}		
n_D^{30}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		----
100°C		0.9
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		48.1
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		----
Lead Azide		0.30
Tetryl		----
Ballistic Mortar, % TNT:		100
Trauzl Test, % TNT:		107
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Pressed
Charge Diameter, in.		0.5
Density, gm/cc		1.72
Rate, meters/second		7300

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Yellow
For TNT	
For Subject HE	**Principal Uses:** High temperature heat resistant explosive
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	**Method of Loading:** Pressed
Total No. of Fragments:	
For TNT	**Loading Density:** gm/cc
For Subject HE	At 50,000 psi 1.72
Fragment Velocity: ft/sec	**Storage:**
At 9 ft	Method: Dry
At 25½ ft	Hazard Class (Quantity-Distance): Class 9
Density, gm/cc	Compatibility Group: Group I
Blast (Relative to TNT):	Exudation: None
Air: 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.
Air, Confined: Impulse	**Heat of:**
Under Water: Peak Pressure, Impulse, Energy	Combustion, cal/gm (a) 2962
Underground: Peak Pressure, Impulse, Energy	Explosion, cal/gm 564
	Formation, cal/gm (a) 131

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 39, 853). The use of picramide, as a brisant explosive, was patented by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reacted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H_2SO_4 at about 5°C with concentrated HNO_3 (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).

[58] See footnote 1, page 10.

Picratol, 52/48

Composition:		
	%	
Explosive D	52	
TNT	48	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm		100+
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		17
Sample Wt, mg		19
Friction Pendulum Test:		
Steel Shoe		Unaffected
Fiber Shoe		Unaffected
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	0	
Partials	0	
Burned	40	
Unaffected	60	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	456	
1	354	
5 Decomposes	285	
10	265	
15	260	
20	255	
75°C International Heat Test:		
% Loss in 48 Hrs		0.0
100°C Heat Test:		
% Loss, 1st 48 Hrs		0.0
% Loss, 2nd 48 Hrs		0.05
Explosion in 100 Hrs		None
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH		0.02
Volatility:		

Molecular Weight:		236
Oxygen Balance:		
CO_2 %		-63
CO %		-19
Density: gm/cc	Cast	1.62
Melting Point: °C		
Freezing Point: °C		
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		0.37
120°C		0.68
135°C		--
150°C		0.7
200 Gram Bomb Sand Test:		
Sand, gm		45.0
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.05
Ballistic Mortar, % TNT:	(a)	100
Trauzl Test, % TNT:		
Plate Dent Test:	(b)	
Method		B
Condition		Cast
Confined		No
Density, gm/cc		1.63
Brisance, % TNT		100
Detonation Rate:	(b)	
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.63
Rate, meters/second		6970

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, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.61
Charge Wt, lb	0.850
Total No. of Fragments:	
For TNT	514
For Subject HE	487

Fragment Velocity: ft/sec

At 9 ft	2590
At 25½ ft	2320
Density, gm/cc	1.62

Blast (Relative to TNT):

Air:	
Peak Pressure	100
Impulse	100
Energy	--
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft	10,000-12,000

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

Preparation:

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.

Origin:

Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler.

Booster Sensitivity Test: (c)

Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	1.00
Density, gm/cc	1.63

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:

0	5	6	7	8	9
1470	1885	1466	1737	1838	1729
		1796	1797		
		1956			

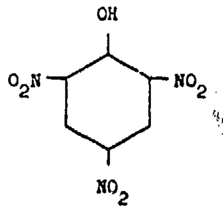
[59] See footnote 1, page 10.

Picric Acid

Composition:

%	
C	31.5
H	1.3
N	18.3
O	48.9

C/H Ratio 0.656



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	85
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	13
Sample Wt, mg	17

Friction Pendulum Test:

Steel Shoe

Fiber Shoe

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	60
Burned	40
Unaffected	0

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		
1		
5	Decomposes	320
10		
15		
20		

75°C International Heat Test:

% Loss in 48 Hrs	0.05

100°C Heat Test:

% Loss, 1st 48 Hrs	0.03
% Loss, 2nd 48 Hrs	0.09
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.04

Volatility:

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

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	0.2
120°C	0.5
135°C	
150°C	

200 Gram Bomb Sand Test:

Sand, gm	48.5

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	0.26*
Lead Azide	0.24*
Tetryl	

*Alternative initiating charges.

Ballistic Mortar, % TNT: (a) 112

Trauzl Test, % TNT: (b) 101

Plate Dent Test: (c)

Method	A
Condition	Pressed
Confined	No
Density, gm/cc	1.50
Brisance, % TNT	107

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

Booster Sensitivity Test: (c)

Condition	Pressed	Cast
Tetryl, gm	10	5
Wax, in. for 50% Detonation		
Wax, gm	2	0
Density, gm/cc	1.6	1.7

Heat of:

Combustion, cal/gm	2672
Explosion, cal/gm	1000
Gas Volume, cc/gm	675
Formation, cal/gm	248
Fusion, cal/gm (e)	20.4
Temperature, °C	122

Specific Heat: cal/gm/°C (e)

°C	
0	0.235
30	0.258
60	0.282
90	0.310
120	0.337

Burning Rate:
cm/sec

Thermal Conductivity: (f)
cal/sec/cm/°C 6.24×10^{-4}
Density, gm/cc 1.406

Coefficient of Expansion:
Linear, %/°C

Volume, %/°C

Hardness, Mohs' Scale: 2.1

Young's Modulus:
E', dynes/cm²
E, lb/inch²
Density, gm/cc

Compressive Strength: lb/inch²

Vapor Pressure:

°C	mm Mercury
195	2
255	50

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

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

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

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-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

Principal Uses: Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D

Method of Loading: Pressed

Loading Density: gm/cc psi x 10^3

3	5	10	12	15	20
1.40	1.50	1.57	1.59	1.61	1.64

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None

Picric Acid

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

Water

°C	%
0	0.85
20	1.17
40	1.88
60	2.98
80	4.53
100	7.1

Alcohol

°C	%
0	4.5
20	6.9
40	12.0

Benzene

°C	%
0	~2
20	9.6
40	27.5
60	59

Toluene

°C	%
20	~13
60	~30

Ether

°C	%
20	~3
34.7	3.96

Chloroform

°C	%
20	~2
60	~[illegible]

Ethyl acetate

°C	%
20	42
30	50
40	58
50	69

Carbon tetrachloride

°C	%
20	~0.07
60	~0.4

Pyridine

°C	%
10	24
30	37.5
50	58

Acetone

°C	%
20	125
30	137
40	164
50	208

Methanol

°C	%
0	14
20	19
40	31
50	41

Isopropyl alcohol

°C	%
10	6.4
30	9.8
50	15.5

Propanol-1

°C	%
0	2.4
20	3.3
40	5.4
50	7.4

Carbon disulfide

°C	%
20	0.12
30	0.16

Preparation: (Summary Report of NDRC, Div 8, Vol I)

$$C_6H_6 + Hg(NO_3)_2 \longrightarrow C_6H_5HgNO_3 + HNO_3 \qquad (1)$$

$$C_6H_5HgNO_3 + N_2O_4 \longrightarrow C_6H_5NO + Hg(NO_3)_2 \qquad (2)$$

$$C_6H_5NO + 2NO \longrightarrow C_6H_5N_2NO_3 \qquad (3a)$$

$$C_6H_5N_2NO_3 + H_2O \longrightarrow C_6H_5OH + N_2 + HNO_3 \qquad (3b)$$

$$C_6H_5OH + HNO_3 \xrightarrow{NO_2} O_2NC_6H_4OH + H_2O \qquad (3c)$$

$$C_6H_5NO \xrightarrow[\text{oxidation and rearrangement}]{HNO_3} O_2NC_6H_4OH \qquad (4)$$

$$O_2NC_6OH + HNO_3 \xrightarrow{NO_2} (O_2N)_2C_6H_3OH + H_2O \qquad (5)$$

$$(O_2N)_2C_6H_3OH + HNO_3 \xrightarrow{NO_2} (O_2N)_3C_6H_2OH + H_2O \qquad (6)$$

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 over all 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 1888 under the name of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TNT about 1900. Today Picric Acid is used for the manufacture of Explosive D.

Destruction by Chemical Decomposition:

Picric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide ($Na_2S \cdot 9H_2O$) in 200 parts of water. Some hydrogen sulfide and ammonia are evolved.

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-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

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

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

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

(e) International Critical Tables.

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity Explosive Materials, AC Report No. 2861, First Report, August 1942.

(g) Values taken from various sources in the open literature.

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

1	2	3	4	5	6	7	8	9
1651	132	1383	694	65	266	1347	1118	1549
	582		764	425	556	1557		
	1172		874	1585	926			
	1352				976			
	1372				986			
					1446			
					1556			

[60]See footnote 1, page 10.

PIPE

Composition:	
%	
PETN	81
Gulf Crown E Oil	19
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	27
Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
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.	
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
Flammability Index:	
Hygroscopicity: % 30°C, 90% RH	0.02
Volatility:	

Molecular Weight:		310
Oxygen Balance:		
CO_2 %		-74
CO %		-31
Density: gm/cc	Hand tamped	1.35
Melting Point: °C		
Freezing Point: °C		
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		0.48
120°C	16 hours	11+
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		41.6
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:		
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

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

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

Preparation:

PIPE is manufactured by simple mechanical mixing of PETN in oil.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.35

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, Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

(b) S. Livingston, Properties of Explosives RIPE, PIPE and PEP-3, Picatinny Arsenal Technical Report 1517, 24 April 1945.

[61]See footnote 1, page 10.

Plumbatol

Composition: %	
Lead Nitrate	70
TNT	30
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	13
Sample Wt, mg	22
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	238
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	
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:	291
Oxygen Balance:	
CO_2 %	-5.4
CO %	+9.3
Density: gm/cc	
Melting Point: °C	
Freezing Point: °C	
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	
120°C	
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	32.4
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	--
Lead Azide	0.20
Tetryl	0.10
Ballistic Mortar, % TNT:	
Trauzl Test, % TNT:	
Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detonation Rate: (b)	
Confinement	
Condition	
Charge Diameter, in.	
Density, gm/cc	2.89
Rate, meters/second	4850

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones (a)
Density, gm/cc	Hole Volume 114
Charge Wt, lb	Hole Depth 103
Total No. of Fragments:	**Color:** Light yellow
For TNT	
For Subject HE	
3 inch HE, M42A1 Projectile, Lot KC-5:	**Principal Uses:**
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Cast
For TNT	
For Subject HE	
Fragment Velocity: ft/sec	**Loading Density:** gm/cc
At 9 ft	
At 25½ ft	
Density, gm/cc	
Blast (Relative to TNT):	**Storage:**
Air:	Method: Dry
Peak Pressure	Hazard Class (Quantity-Distance): Class 9
Impulse	Compatibility Group: Group I
Energy	Exudation
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	

Preparation:

Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.

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, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W-672-ORD-5723.

(b) Thorpe's Dictionary of Applied Chemistry, Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.

[62]See footnote , page 10.

PLX (Liquid)

Composition:		
%		*
Nitromethane	100	95
Ethylenediamine	--	5
*The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under Storage.		
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:	100	95/5
Bureau of Mines Apparatus, cm	100+	100+
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.		
Sample Wt, mg	20	20
Friction Pendulum Test:		
Steel Shoe	Unaffected	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	10 Trials	5 Trials
	%	%
Explosions	0	0
Partials	0	0
Burned	0	0
Unaffected	100	100
Explosion Temperature:	°C	°C
Seconds, 0.1	100	95/5
1		
5	430	430
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		
Flammability Index:		
Hygroscopicity: %		
Volatility:		

Molecular Weight:	100 61	95/5 61
Oxygen Balance:		
CO_2 %	-39	-48
CO %	-13	-21
Density: gm/cc	1.14	1.12
Melting Point: °C	-29	
Freezing Point: °C		
Boiling Point: °C	101	
Refractive Index, n_D^{20}		
n_D^{25}		
n_D^{30}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:	100	95/5
Sand, gm	8.1	50.6
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:	134	
Trauzl Test, % TNT	127	
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:	1/32"*	1/32"*
Confinement	Glass	Glass
Condition	Liquid	Liquid
Charge Diameter, in.	1.25	0.94
Density, gm/cc	1.14	1.12
Rate, meters/second	6210	6165

*Tube wall thickness

Booster Sensitivity Test: Nitromethane	**Decomposition Equation:** (d) Nitromethane
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 380-430
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 Bombs:**
Fusion, cal/gm	Plate Thickness, inches
Vaporization, cal/gm 149	1
Specific Heat: cal/gm/°C (b)	1¼
$C_p = 0.4209 - 0.00076t + 0.0000061t^2$ for 15°C to 70°C	1½
	1¾
Burning Rate: cm/sec	**Bomb Drop Test:**
Thermal Conductivity: cal/sec/cm/°C	**T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:**
	Max Safe Drop, ft
Coefficient of Expansion:	**500-lb General Purpose Bomb vs Concrete:**
Linear, %/°C	Height, ft
Volume, %/°C	Trials
Hardness, Mohs' Scale:	Unaffected
Young's Modulus:	Low Order
E', dynes/cm²	High Order
E, lb/inch²	**1000-lb General Purpose Bomb vs Concrete:**
Density, gm/cc	Height, ft
Compressive Strength: lb/inch²	Trials
Vapor Pressure: (c)	Unaffected
°C / mm Mercury	Low Order
70 / 258	High Order
85 / 441	

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-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: Light yellow

Principal Uses: Minefield clearing

Method of Loading: Pumping

Loading Density: gm/cc	100	95/5
	1.14	1.12

Storage:

Method	Components stored separately; mixed only when ready to use
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	

Minimum Propagating Thickness, in:	100	95/5
	0.5	0.063

Viscosity, centipoises:	(*)
Temp, 10°C	0.748
25°C	0.625
40°C	0.533

Compatibility with Metals:

Stainless steel, mild steel and duriron not affected; corrodes brass.

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. Médard, "Explosive Properties of Nitromethane," Mém 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).

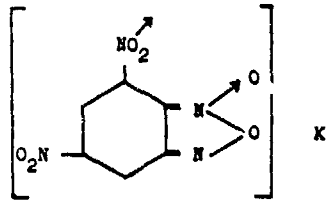
(f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

0	1	3	5	6	7	8	9
1660	1681	2113	1565	2016	1747	1708	1619
	1831						

[63] See footnote 1, page 10.

Potassium Dinitrobenzfuroxan (KDNBF)

Composition:	
%	
C	27.3
H	0.4
N	21.2
O	36.3
K	14.8



C/H Ratio 0.416

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

Friction Pendulum Test:	
Steel Shoe	Explodes
Fiber Shoe	Explodes

Rifle Bullet Impact Test:	Trials
	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	--
1	--
5	250
10	
15	
20	

75°C International Heat Test:	
% Loss in 48 Hrs	

100°C Heat Test:	
% Loss, 1st 48 Hrs	0.03
% Loss, 2nd 48 Hrs	0.05
Explosion in 100 Hrs	None

Flammability Index:		

Hygroscopicity: %		
	30°C, 75% RH	0.11
	30°C, 90% RH	0.27

Volatility:	

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	

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	
120°C	
135°C	
150°C	

200 Gram Bomb Sand Test:		
Sand, gm	44.8	43.6
Black powder fuse 9.5		

Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate	0.30	0.20
Lead Azide		0.10
Tetryl		

Ballistic Mortar, % TNT:	

Trauzl 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	

Booster Sensitivity Test:	
Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	
Heat of:	
Combustion, cal/gm	2209
Explosion, cal/gm	725
Gas Volume, cc/gm	604
Formation, cal/gm	
Fusion, cal/gm	
Specific Heat: cal/gm/°C (b)	
°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/cm²	
E, lb/inch²	
Density, gm/cc	
Compressive Strength: lb/inch²	
Vapor Pressure:	
°C	mm Mercury

Decomposition Equation:	
Oxygen, atoms/sec	
(Z/sec)	
Heat, kilocalorie/mole	
(ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	

Potassium Dinitrobenzfuroxan (KDNBF)

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: Orange to brown

Principal Uses: Primary explosive

Method of Loading: Pressed

Loading Density: gm/cc

psi x 10^3	10	20	30	40	80
gm/cc	1.63	1.77	1.81	1.86	1.98

Storage:

Method	Wet
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group M (wet)
Exudation	

Solubility in Water, gm/100 gm solvent, at:

30°C 0.245

Stab Sensitivity:

Density gm/cc	Firing Point (inch-ounces) 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

Activation Energy:

kcal/mol	82.6
Induction Period, sec	0.5-10

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. Lenchitz, 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:

2	3	6	9
2122	2093	2146	2179

[64]See footnote 1, page 10.

Composition:	
%	
RDX	30
Tetryl	50
TNT	20
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	44
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
Sample Wt, mg	
Friction Pendulum Test:	
Steel Shoe	
Fiber Shoe	
Rifle Bullet Impact Test: Trials	
	%
Explosions	20
Partials	20
Burned	0
Unaffected	60
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	
1	
5	
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	
Flammability Index:	
Hygroscopicity: %	
30°C, 90% RH, 15 days	0.00
Volatility:	

Molecular Weight:		252
Oxygen Balance:		
CO_2 %		-45
CO %		- 9
Density: gm/cc		1.68
Melting Point: °C	Eutectic	67
Freezing Point: °C		
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		3.0
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		54.8
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.23*
Lead Azide		0.22*
Tetryl		
*Alternative initiating charges.		
Ballistic Mortar, % TNT:	(a)	132
Trauzl Test, % TNT:		
Plate Dent Test:	(b)	
Method		B
Condition		Cast
Confined		No
Density, gm/cc		1.68
Brisance, % TNT		127
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.64
Rate, meters/second		7655

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-5:

Density, gm/cc	1.63
Charge Wt, lb	0.864

Total No. of Fragments:

For TNT	514
For Subject HE	685

Fragment Velocity: ft/sec

At 9 ft	2690
At 25½ ft	2460
Density, gm/cc	1.64

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	

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

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Land mines and demolition charges

Method of Loading: Cast

Loading Density: gm/cc 1.68

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes at 65°C

Preparation:

The ternary explosive system consisting of RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetrytol (40/60) previously melted in a steam-jacketed melt kettle. 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.

PTX-1

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/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:

0	2	3	6	7	9
1530	1402	1623	1466	1437	1379
			1506		1429
					1469

[65] See footnote 1, page 10.

Composition: %		**Molecular Weight:**	244 243
RDX	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
		Melting Point: °C	Eutectic 75
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		**Boiling Point:** °C	
Bureau of Mines Apparatus, cm	35	**Refractive Index,** n_D^{20}	
Sample Wt 20 mg		n_D^{25}	
Picatinny Arsenal Apparatus, in.		n_D^{30}	
Sample Wt, mg			
Friction Pendulum Test:		**Vacuum Stability Test:**	
Steel Shoe	Crackles	cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test:	Trials %	100°C	2.6
Explosions	60	120°C	11+
Partials	0	135°C	
Burned	0	150°C	
Unaffected	40	**200 Gram Bomb Sand Test:**	
		Sand, gm	56.9
Explosion Temperature:	°C	**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.21
5		Lead Azide	0.00
10		Tetryl	0.00
15		**Ballistic Mortar, % TNT:** (a)	138
20		**Trauzl Test, % TNT:**	
75°C International Heat Test:		**Plate Dent Test:** (b)	
% Loss in 48 Hrs		Method	B
100°C Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs		Confined	No
% Loss, 2nd 48 Hrs		Density, gm/cc	1.71
Explosion in 100 Hrs		Brisance, % TNT	141
Flammability Index:		**Detonation Rate:**	
		Confinement	None
Hygroscopicity: %		Condition	Cast
30°C, 90% RH, 15 days	0.00	Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.70
		Rate, meters/second	8065

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

Fragment Velocity: ft/sec

At 9 ft	3020
At 25½ ft	2850
Density, gm/cc	1.70

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	

Booster Sensitivity Test: (c)

Condition	Pressed	Cast
Tetryl, gm	100	100
Wax, in. for 50% Detonation	1.87	2.32
Density, gm/cc	1.70	1.61

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume	~130	
Hole Depth		

Color:

Principal Uses: Shaped charges
Fragmentation charges

Method of Loading: Cast

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:

Dry: Aluminum, mild steel not affected.

Wet: Aluminum not affected.

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor-piercing high explosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDX/PETN/TNT, designated PTX-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR No. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered promise but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References:[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:

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

[66]See footnote 1, page 10.

PVA-4

Composition:	
%	
RDX	90
Polyvinyl Acetate	8
Dibutylphthalate	2
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	39
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	9
Sample Wt, mg	13
Friction Pendulum Test:	
Steel Shoe	Crackles
Fiber Shoe	Unaffected
Rifle Bullet Impact Test: 5 Trials *	
	%
Explosions	20
Partials	0
Burned	60
Unaffected	20
*100 trials at -46°C - Unaffected	
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	--
1	330
5 Decomposes	375
10	265
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.10
% Loss, 2nd 48 Hrs	0.06
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: % 30°C, 90% RH	0.20
Volatility: 55°C, vacuo, 6 hrs	0.03

Molecular Weight:		217
Oxygen Balance:		
CO_2 %		-37
CO %		-10
Density: gm/cc	Pressed	1.60
Melting Point: °C		
Softening Point: °C		92
Freezing Point: °C		
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		0.88
135°C		--
150°C		11+
200 Gram Bomb Sand Test:		
Sand, gm		58.5
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.22
Tetryl		
Ballistic Mortar, % TNT:		
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.60
Rate, meters/second		7910

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: White

Principal Uses: Demolition charges

Method of Loading: Pressed or extruded

Loading Density: gm/cc 1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None at 71°C

Plasticity:

-40°C	Cracked
25°C	0.3

PVA-4

Preparation:

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.

[67] See footnote 1, page 10.

Composition:		
%		
C	27	
H	3.4	$(H_2C\text{-}CH\text{-}ONO_2)_n$
N	15.6	
O	54	
C/H Ratio 0.203		
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		
Friction Pendulum Test:		
Steel Shoe	Crackles	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test: Trials		
	%	
Explosions		
Partials		
Burned		
Unaffected		
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)	--	
1	--	
5	265	
10		
15		
20		
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	
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH	0.62	
Volatility:		

Molecular Weight: $(C_2H_3NO_3)_n$		$(89)_n$
Oxygen Balance:		
CO_2 %		-45
CO %		- 9
Density: gm/cc		
Melting Point: °C (Soft Pt)		50
Freezing Point: °C		
Boiling Point: °C		
Refractive Index, n_D^{20}		
n_D^{25}		
n_D^{30}		
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
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		--
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:		
Trauzl 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		

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:

Principal Uses:

Method of Loading:

Loading Density: gm/cc

Storage:

Method

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

65.5°C KI Test:

Minutes	60+

134.5°C Heat Test:

	Minutes
Salmon Pink	20
Red Fumes	25
Explodes	300+

240-Hour Hydrolysis Test:

% HNO_3	5.07

Heat of:

Combustion, cal/gm	2960
Explosion, cal/gm	900
Gas Volume, cc/gm	838

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).

Composition:	
%	
RDX	85
Gulf Crown E Oil	15
C/H Ratio	

Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	53
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	13
Sample Wt, mg	25

Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected

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; no value obtained
10	
15	
20	

75°C International Heat Test:	
% Loss in 48 Hrs	

100°C Heat Test:	
% Loss, 1st 48 Hrs	0.03
% Loss, 2nd 48 Hrs	0.04
Explosion in 100 Hrs	None

Flammability Index:	
Hygroscopicity: % 30°C, 90% RH	0.04
Volatility:	

Molecular Weight:	230
Oxygen Balance:	
CO_2 %	-70
CO %	-35
Density: gm/cc Hand tamped	1.37
Melting Point: °C	
Freezing Point: °C	
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	0.34
120°C	0.56
135°C	
150°C	

200 Gram Bomb Sand Test:	
Sand, gm	40.1

Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	
Lead Azide	0.20
Tetryl	

Ballistic Mortar, % TNT: (a)	118
Trauzl Test, % TNT:	

Plate Dent Test: (b)	
Method	B
Condition	Hand tamped
Confined	No
Density, gm/cc	1.37
Brisance, % TNT	85

Detonation Rate:	
Confinement	None
Condition	Hand tamped
Charge Diameter, in.	1.0
Density, gm/cc	1.37
Rate, meters/second	7390

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, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.42
Charge Wt, lb	0.756

Total No. of Fragments:

For TNT	514
For Subject HE	501

Fragment Velocity: ft/sec

At 9 ft	2650
At 25½ ft	2370
Density, gm/cc	1.395

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.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: White

Principal Uses: Plastic demolition explosive

Method of Loading: Hand tamped

Loading Density: gm/cc 1.37

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

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, 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) Also see the following Picatinny Arsenal Technical Reports on RIPE: 1713, 1695 and 1517.

[68]See footnote 1, page 10.

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.
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6; Sample Wt 20 mg; Picatinny Arsenal Apparatus, in. 3; Sample Wt, mg 18	**Boiling Point:** °C
	Refractive Index, n°_{D} n°_{D} n°_{D}
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
Rifle Bullet Impact Test: Trials %; Explosions; Partials; Burned; Unaffected	
	200 Gram Bomb Sand Test: Sand, gm (b) Black powder fuse 18.9
Explosion Temperature: °C; Seconds, 0.1 (no cap used) 310; 1 --; 5 Explodes 290; 10; 15; 20	**Sensitivity to Initiation:** Minimum Detonating Charge, gm; Mercury Fulminate; Lead Azide; Tetryl
	Ballistic Mortar, % TNT:
	Trauzl Test, % $Hg(ONC)_2$ (c) 88
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	
Flammability Index:	**Detonation Rate:** Confinement; Condition; Charge Diameter, in.; Density, gm/cc; Rate, meters/second
Hygroscopicity: % (b) 25°C, 100% RH 0.04	
Volatility: 25°C, 24 hrs 0.00	

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones / Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** White to gray
For TNT	**Principal Uses:** Initiators
For Subject HE	**Method of Loading:** Pressed
3 inch HE, M42A1 Projectile, Lot KC-5:	**Loading Density:** gm/cc Variable
Density, gm/cc	**Storage:**
Charge Wt, lb	Method: Wet
Total No. of Fragments:	Hazard Class (Quantity-Distance): Class 9
For TNT	Compatibility Group: Group M
For Subject HE	Exudation: None
Fragment Velocity: ft/sec	Initiating Efficiency:
At 9 ft	Grams Required to Give Complete Initiation of TNT (c): 0.02-0.05
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

Explosive Power: (f)

Kilogram meters	192,000
% Mercury Fulminate	1.097

Solubility in 100 gm Solvent at Room Temperature:

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)

Heat of:

Explosion, cal/gm	(c, d)	452
Formation, cal/gm	(e)	67.8

Preparation:

$NaN_3 + AgNO_3 \longrightarrow AgN_3 \downarrow + NaNO_3$

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 "collodial" 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).

[69] See footnote 1, page 10.

(g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.

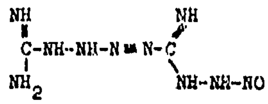
(h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).

(i) F. G. Haverlak, Examination of 120/45 MM HE Shell, Italian (FMAM-464), PATR No. 1515, 10 April 1945.

Tetracene

Composition:

%	
C	12.8
H	4.3
N	74.4
O	8.5



C/H Ratio 0.068

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	7
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.; (8 oz wt)	8
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	160
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs	0.5

100°C Heat Test:

% Loss, 1st 48 Hrs	23.2
% Loss, 2nd 48 Hrs	3.4
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.77

Volatility:

Molecular Weight: ($C_2H_8N_{10}O$) 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

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

120°C

135°C

150°C

200 Gram Bomb Sand Test:

Sand, gm	28.0
Black powder fuse 4.0	

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate	0.40
Lead Azide	
Tetryl	

Ballistic Mortar, % TNT:

Trauzl Test, % TNT: (a) 61

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

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: Pale yellow

Principal Uses: Priming compositions and detonators

Method of Loading: Pressed

Loading Density: gm/cc
At 3000 psi 1.05

Storage:

Method	Wet
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)

Unconfined	0.010
Confined	0.012

Heat of:

Explosion, cal/gm	658
Gas Volume, cc/gm	1190

Initiating Efficiency:

Tetracene is not efficient in initiating high explosives.

Tetracene

Preparation:

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

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

(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

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

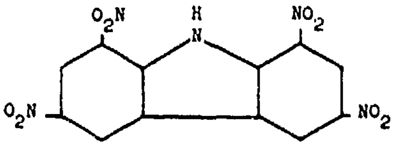
0	1	3	4	7	8	9
1450	11	453	1104	407	318	859
			2164			2179

[70] See footnote 1, page 10.

Composition:

%	
C	41.6
H	1.4
N	20.0
O	37.0

C/H Ratio 1.032



Molecular Weight: ($C_{12}H_5N_5O_8$) 347

Oxygen Balance:

CO_2 %	-85
CO %	-30

Density: gm/cc

Melting Point: °C Pure 1,3,6,8-isomer 296

Freezing Point: °C

Boiling 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

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	0.2
120°C	0.2
135°C	
150°C	

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

200 Gram Bomb Sand Test:

Sand, gm 41.3

Explosion Temperature: °C

	°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:

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	0.15
% Loss, 2nd 48 Hrs	0.05
Explosion in 100 Hrs	None

Flammability Index:

Detonation Rate:

Confinement

Condition

Charge Diameter, in.

Density, gm/cc

Rate, meters/second

Hygroscopicity: % 30°C, 90% RH 0.01

Volatility:

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, 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: Light yellow

Principal Uses: Component of igniter and pyrotechnic compositions

Method of Loading: Pressed

Loading Density: gm/cc

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Solubility in Water, gm/100 gm (%), at:

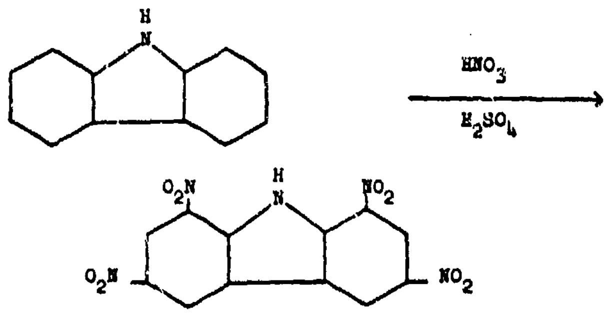
95°C	0.10

Qualitative Solubilities:

Solvent	Solubility
Nitrobenzene	Very soluble
Acetone	Soluble
Benzene	Insoluble
Chloroform	Insoluble
Carbontetrachloride	Insoluble
Ether	Insoluble
Ether, petroleum	Insoluble

Tetranitrocarbazole (TNC)

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. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 1909)). However, G. L. Ciamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital 12, 272 1882). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,538). The Casella process of 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:

0	2	3	4	7
2180	1802	1973	1984	1647
				1937

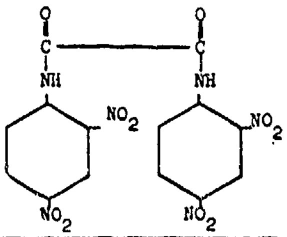
[71] See footnote 1, page 10.

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

Composition:

%	
C	40.0
H	1.9
N	20.0
O	38.1

C/H Ratio 0.735



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	--
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	30
Sample Wt, mg	11

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	--
1	--
5	392
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.07
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: % 30°C, 90% RH — Trace

Volatility:

Molecular Weight: ($C_{14}H_8N_6O_{10}$) 420

Oxygen Balance:

CO_2 %	-84
CO %	-31

Density: gm/cc

Melting Point: °C Decomposes 313

Freezing Point: °C

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	--
120°C	0.11
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 16.3

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	
Lead Azide	0.20
Tetryl	0.25

Ballistic Mortar, % TNT:

Trauzl 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

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-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: Light yellow

Principal Uses: Component of black powder type and pyrotechnic compositions

Method of Loading: Pressed and extruded compositions

Loading Density: gm/cc

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	
Exudation	

Solubility, gm/100 cc Solvent, in:

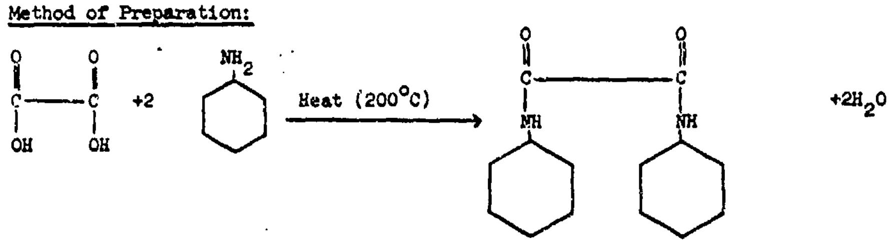
	°C	%
Water	100	<0.10
Nitrobenzene	150	>15

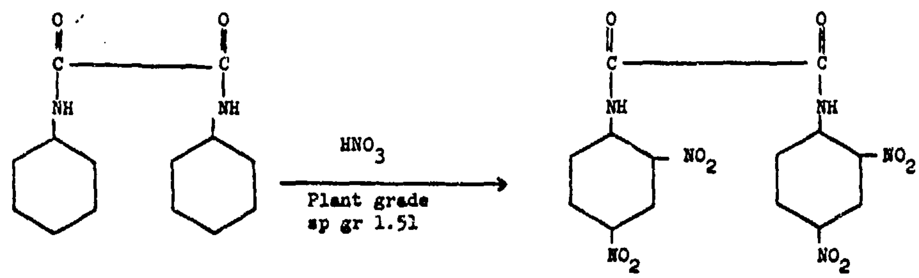
Qualitative Solubilities:

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

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

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 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.

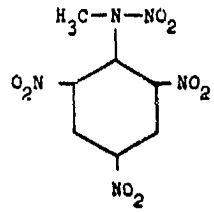
(b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-38, 20 December 1954.

[72] See footnote 1, page 10.

Composition:

%	
C	29.3
H	1.7
N	24.4
O	44.6

C/H Ratio 0.420



Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	26
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	8
Sample Wt, mg	18

Friction Pendulum Test:

Steel Shoe	Crackles
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	13
Partials	54
Burned	10
Unaffected	23

Explosion Temperature: °C

Seconds, 0.1 (no cap used)		340
1		314
5	Ignites	257
10		238
15		236
20		234

75°C International Heat Test:
% Loss in 48 Hrs 0.01

100°C Heat Test:

% Loss, 1st 48 Hrs	0.1
% Loss, 2nd 48 Hrs	0.0
Explosion in 100 Hrs	None

Flammability Index: 244

Hygroscopicity: % 30°C, 90% RH 0.04

Volatility: 25°C 0.00

Molecular Weight: ($C_7H_5N_5O_8$) 287

Oxygen Balance:

CO_2 %	-47
CO %	- 8

Density: gm/cc Crystal 1.73

Melting Point: °C 130

Freezing Point: °C

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	1.0
135°C	--
150°C	11+

200 Gram Bomb Sand Test:
Sand, gm 54.2

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	0.20*
Lead Azide	0.10*

Tetryl
*Alternative initiating charges.

Ballistic Mortar, % TNT: (a) 130

Trauzl Test, % TNT: (b) 125

Plate Dent 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

Detonation Rate:

Confinement	None
Condition	Pressed
Charge Diameter, in.	1.0
Density, gm/cc	1.71
Rate, meters/second	7850

Booster Sensitivity Test:	(d)	
Condition	Pressed	
Tetryl, gm	100	
Wax, in. for 50% Detonation	2.01	
Wax, gm		
Density, gm/cc	1.58	

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

Specific Heat: cal/gm/°C	(e)
°C	
-100	0.182
- 50	0.200
0	0.212
50	0.223
100	0.236

Burning Rate:
cm/sec

Thermal Conductivity: (f)
cal/sec/cm/°C 5.81×10^{-4} at 1.394 gm/cc
6.83×10^{-4} at 1.528 gm/cc

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

Decomposition Equation:	(g)	(h)
Oxygen, atoms/sec (Z/sec)	$10^{15.4}$	$10^{12.9}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	38.4	34.9
Temperature Range, °C	211-260	132-164
Phase	Liquid	Liquid

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
1⅓
1¾

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

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-5:

Density, gm/cc	1.62
Charge Wt, lb	0.848
Total No. of Fragments:	
For TNT	514
For Subject HE	605

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: Light yellow

Principal Uses: Boosters; ingredient of explosive mixtures, detonators, and blasting caps

Method of Loading: Pressed

Loading Density: gm/cc See below

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class [illegible]
Compatibility Group	Group [illegible]
Exudation	Does not exude at 65°C

Loading Density: gm/cc

Cast 1.62 Pressed psi x 10^3

0	3	5	10	12	15	20	30
0.9	1.40	1.47	1.57	1.60	1.63	1.67	1.72

Effect of Temperature on Rate of Detonation: (;)

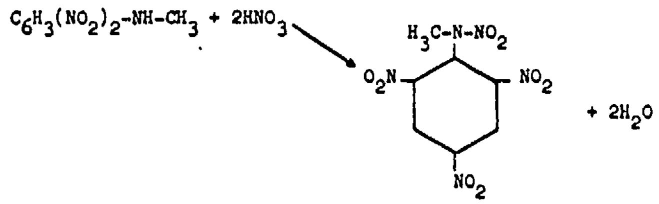
16 hrs at, °C	-54	21
Density, gm/cc	1.52	1.53
Rate, m/sec	7150	7170

Tetryl

Preparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Co., Inc.)

$$C_6H_3(NO_2)_2Cl + CH_3NH_2 + NaOH \longrightarrow C_6H_3(NO_2)_2\text{-NH-}CH_3 + NaCl + H_2O$$



To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C).

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.8/18.2 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.

Tetryl

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

Unconfined	0.007
Confined	4.4

Solubility of tetryl, grams in 100 grams (%) of:

Water

°C	%
0	0.0050
20	0.0075
40	0.0110
80	0.0810
100	0.184

Carbon tetrachloride

°C	%
0	0.007
20	0.015
40	0.058
60	0.154

Ether

°C	%
0	0.188
10	0.330
20	0.418
30	0.493

95% Alcohol

°C	%
0	0.320
10	0.425
20	0.563
30	0.76
50	1.72
75	5.33

Chloroform

°C	%
0	0.28
20	0.39
40	1.20
60	2.65

Carbon disulfide

°C	%
0	0.009
10	0.015
20	0.021
30	0.030

Ethylene dichloride

°C	%
25	4.5
75	45

Acetone

°C	%
20	75
30	95
40	116
50	138

Trichloroethylene

°C	%
0	0.07
20	0.12
40	0.26
60	0.67
80	1.50
86	1.76

Ethyl acetate

°C	%
20	~40

Benzene

°C	%
20	7.8
30	10.0
40	12.5
50	16.0

Toluene

°C	%
20	8.5

Xylene

°C	%
20	3.3
30	4.4
40	5.4
50	6.0

TNT

°C	%
80	82
100	149
120	645

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite ($Na_2SO_3 \cdot 7H_2O$) 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---Sprengstoffw, pp. 181, 229, 267 (27 June 1932).

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

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

(e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104

(f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.

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

(h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah. Ind Eng Chem 1090-1095 (June 1956).

(i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

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

(k) Also see the following Picatinny Arsenal Technical Reports on Tetryl:

0	1	2	3	4	5	6	7	8	9
30	11	132	453	84	65	266	117	28	129
600	261	582	493	144	195	556	197	438	179
770	381	832	623	294	425	786	637	628	319
810	621	882	833	314	525	986	707	708	609
1180	861	1192	863	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
1370	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
1670	1651			1264	1585	1636	1437		1819
				2024	1885	1956	1737		1969
				2204	1935		1797		
					2105		1937		
					2125				
					2205				

[73] See footnote 1, page 10.

Composition: %		**Molecular Weight:**	274
Tetryl	80	**Oxygen Balance:**	
TNT	20	CO_2 %	-52
		CO %	-11
		Density: gm/cc Cast	1.51
		Melting Point: °C	68
C/H Ratio		**Freezing Point:** °C	
Impact Sensitivity, 2 Kg Wt:		**Boiling Point:** °C	
Bureau of Mines Apparatus, cm	28	**Refractive Index,** n^{20}_{D}	
Sample Wt 20 mg		n^{25}_{D}	
Picatinny Arsenal Apparatus, in.	9	n^{30}_{D}	
Sample Wt, mg	17		
Friction Pendulum Test:		**Vacuum Stability Test:**	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
Rifle Bullet Impact Test: Trials %		100°C	3.0
Explosions	0	120°C	11+
Partials	20	135°C	
Burned	0	150°C	
Unaffected	80	**200 Gram Bomb Sand Test:**	
		Sand, gm	54.0
Explosion Temperature: °C		**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.22*
5 Ignites	290	Lead Azide	0.17*
10		Tetryl	
15		*Alternative initiating charges.	
20		**Ballistic Mortar, % TNT:**	
		Trauzl Test, % TNT:	
75°C International Heat Test:		**Plate Dent Test:**	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.1	Confined	
% Loss, 2nd 48 Hrs	0.5	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index: Will not continue to burn		**Detonation Rate:**	
		Confinement	
Hygroscopicity: %	0.02	Condition	
		Charge Diameter, in.	
Volatility:		Density, gm/cc	
		Rate, meters/second	

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-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: Light yellow to buff

Principal Uses: Bursters, demolition blocks

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes at 65°C

Composition:		
%		
Tetryl	75	
TNT	25	
C/H Ratio		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	28	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.	10	
Sample Wt, mg	17	
Friction Pendulum Test:		
Steel Shoe	Cracks	
Fiber Shoe	Unaffected	
Rifle Bullet Impact Test:	Trials	
	%	
Explosions	0	
Partials	30	
Burned	0	
Unaffected	70	
Explosion Temperature:	°C	
Seconds, 0.1 (no cap used)		
1		
5	Ignites	310
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		
Flammability Index: Will not continue to burn		
Hygroscopicity: %	0.03	
Volatility:		

Molecular Weight:		270
Oxygen Balance:		
CO_2 %		-54
CO %		-12
Density: gm/cc	Cast	1.59
Melting Point: °C		68
Freezing Point: °C		
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		3.0
120°C		11+
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		53.7
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.23*
Lead Azide		0.19*
Tetryl		
*Alternative initiating charges.		
Ballistic Mortar, % TNT:	(a)	122
Trauzl Test, % TNT:		
Plate Dent Test:	(b)	
Method	B	B
Condition	Cast	Cast
Confined	No	Yes
Density, gm/cc	1.66	1.62
Brisance, % TNT	118	114
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.60
Rate, meters/second		7385

Fragmentation Test:	
90 mm HE, M71 Projectile, Lot WC-91:	
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 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	(d)
Hole Volume	127		
Hole Depth	120		

Color: Light yellow to buff

Principal Uses: Bursters, demolition blocks

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

Composition:

%	
Tetryl	70
TNT	30

C/H Ratio

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	28
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	18

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	0
Partials	55
Burned	0
Unaffected	45

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	416
1	387
5 Ignites	320
10	302
15	289
20	275

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.1
% Loss, 2nd 48 Hrs	0.1
Explosion in 100 Hrs	None

Flammability Index: Will not continue to burn

Hygroscopicity: % 0.02

Volatility:

Molecular Weight: 266

Oxygen Balance:

CO_2 %	-55
CO %	-13

Density: gm/cc Cast 1.60

Melting Point: °C 68

Freezing Point: °C

Boiling Point: °C

Refractive Index, n, n, n

Vacuum Stability Test:

cc/40 Hrs, at	
90°C	
100°C	3.2
120°C	11+
135°C	
150°C	

200 Gram Bomb Sand Test:
Sand, gm 53.2

Sensitivity to Initiation:
Minimum Detonating Charge, gm

Mercury Fulminate	0.23*
Lead Azide	0.22*
Tetryl	

*Alternative initiating charges.

Ballistic Mortar, % TNT: (a) 120

Trauzl Test, % TNT:

Plate Dent Test: (b)

Method	B
Condition	Cast
Confined	Yes
Density, gm/cc	1.60
Brisance, % TNT	117

Detonation Rate:

Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.60
Rate, meters/second	7340

Tetrytol, 70/30

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
Charge Wt, lb 2.090	Hole Depth
Total No. of Fragments:	**Color:** Light yellow to buff
For TNT 703	**Principal Uses:** Bursters, demolition blocks
For Subject HE 840	
3 inch HE, M42A1 Projectile, Lot KC-5:	**Method of Loading:** Cast
Density, gm/cc 1.60	**Loading Density:** gm/cc 1.60
Charge Wt, lb 0.842	**Storage:**
Total No. of Fragments:	Method Dry
For TNT 514	Hazard Class (Quantity-Distance) Class 9
For Subject HE 585	Compatibility Group Group I
Fragment Velocity: ft/sec	Exudation Exudes at 65°C
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	

Tetrytol, 65/35

Composition:	
%	
Tetryl	65
TNT	35
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	28
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	11
Sample Wt, mg	17
Friction Pendulum Test:	
Steel Shoe	Cracks
Fiber Shoe	Unaffected
Rifle Bullet Impact Test: Trials	
	%
Explosions	0
Partials	10
Burned	0
Unaffected	90
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	
1	
5 Ignites	325
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	
Flammability Index: Will not continue to burn	
Hygroscopicity: %	0.02
Volatility:	

Molecular Weight:	264
Oxygen Balance:	
CO_2 %	-56
CO %	-14
Density: gm/cc	1.60
Melting Point: °C	68
Freezing Point: °C	
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	2.8
120°C	11+
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	52.6
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.23*
Lead Azide	0.23*
Tetryl	
*Alternative initiating charges.	
Ballistic Mortar, % TNT:	
Trauzl Test, % TNT:	
Plate Dent Test:	
Method	
Condition	
Confined	
Density, gm/cc	
Brisance, % TNT	
Detonation Rate:	
Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.60
Rate, meters/second	7310

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

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:

	(d) Glass Cones	(e) Steel Cones
Hole Volume	133	126
Hole Depth	120	119

Color: Light yellow to buff

Principal Uses: Bursters, demolition blocks

Method of Loading: Cast

Loading Density: gm/cc 1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes at 65°C

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

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 W672-ORD-5723.

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

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

0	1	2	3	5	6	7	8	9
1260	1291	1372	1193	1285	1376	1477	1158	1379
1360	1311		1213	1325	1436	1737	1388	
1420	1451		1363	1885	1466	1797	1838	
1500	1651		1493	2125	1506			
1530	1951							

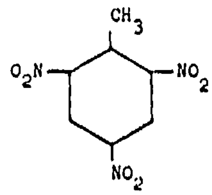
[74] See footnote 1, page 10.

TNT (Trinitrotoluene)

Composition:

%	
C	37.0
H	2.2
N	18.5
O	42.3

C/H Ratio 0.549



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

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	4
Partials	0
Burned	0
Unaffected	6

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	570
1	520
5 Decomposes	475
10	465
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs	0.04

100°C Heat Test:

% Loss, 1st 48 Hrs	0.2
% Loss, 2nd 48 Hrs	0.2
Explosion in 100 Hrs	None

Flammability Index: (b) 100

Hygroscopicity: % 30°C, 90% RH 0.03

Volatility: 30°C Nil

Molecular Weight: ($C_7H_5N_3O_6$) 227

Oxygen Balance:

CO_2 %	-74
CO %	-25

Density: gm/cc Crystal 1.65

Melting Point: °C 81

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_D

α	1.5430
β	1.6742
γ	1.717

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

200 Gram Bomb Sand Test:

Sand, gm	48.0

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

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

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

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

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

Specific Heat: cal/gm/°C

°C	
0	0.309
20	0.328
50	0.353
80	0.374

Burning Rate:
cm/sec

Thermal Conductivity:
cal/sec/cm/°C See next page.

Coefficient of Expansion: (b)

Linear, %/°C	-40° to 60°C	5.4×10^{-5}	(b)
	-40° to 60°C	6.7×10^{-5}	
Volume, %/°C	27° to 80°C	16×10^{-5}	(b)
	16° to 70°C	26.3×10^{-5}	(n)

Hardness, Mohs' Scale: (e) 1.4

Young's Modulus: (b)

E', dynes/cm²	5.45×10^{10}
E, lb/inch²	0.79×10^{6}
Density, gm/cc	161

Compressive Strength: lb/inch² 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

Decomposition Equation:

	(h)	(i)
Oxygen, atoms/sec (Z/sec)	$10^{11.4}$	$10^{12.2}$
Heat, kilocalorie/mole (ΔH, kcal/mol)	34.4	43.4
Temperature Range, °C	275-310	238-277
Phase	Liquid	Liquid

Armor Plate Impact Test:

60 mm Mortar Projectile: (j)
50% Inert, Velocity, ft/sec >1100
Aluminum Fineness

500-lb General Purpose Bombs: (j)

Plate Thickness, inches	Trials	% Inert
1	0	
1¼	0	
1½	4	100
1¾	4	50

Bomb Drop Test:

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft 5000-6000

500-lb General Purpose Bomb vs Concrete:

	No Seal	Seal
Height, ft	4,000	4-5,000
Trials	26	20
Unaffected	24	20
Low Order	2	0
High Order	0	0

1000-lb General Purpose Bomb vs Concrete:

	No Seal	Seal
Height, ft	5,000	5,000
Trials	21	26
Unaffected	18	22
Low Order	0	0
High Order	3	4

TNT (Trinitrotoluene)

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.60
Charge Wt, lb	2.104
Total No. of Fragments:	
For TNT	703
For Subject HE	703

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.60
Charge Wt, lb	0.848
Total No. of Fragments:	
For TNT	514
For Subject HE	514

Fragment Velocity: ft/sec

	(k)
At 9 ft	2600
At 25½ ft	2360
Density, gm/cc	1.58

Blast (Relative to TNT):

Air:	
Peak Pressure	100
Impulse	100
Energy	100
Air, Confined:	
Impulse	100
Under Water:	
Peak Pressure	100
Impulse	100
Energy	100
Underground:	
Peak Pressure	100
Impulse	100
Energy	100

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume	100	100
Hole Depth	100	100

Color: Light yellow

Principal Uses: GP bombs, HE projectiles, demolition charges, depth charges, grenades, propellant compositions

Method of Loading: 1. Cast 2. Pressed

Loading Density: gm/cc See below

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	None at 65°C

Loading Density: gm/cc

1. Cast 1.58-1.59 2. Pressed psi x 10^3

3	5	10	15	20	30	50
1.35	1.40	1.45	1.52	1.55	1.59	1.6

Thermal Conductivity:

cal/sec/cm/°C

Density		
1.19 gm/cc	(g)	5.28×10^{-4}
1.51 gm/cc	(g)	7.12×10^{-4}
1.54 gm/cc	(b)	5.6×10^{-4}
1.67 gm/cc	(g)	12.21×10^{-4}

Viscosity, poises:

Temp, 85°C	0.139
100°C	0.095

Bulk Modulus at Room Temperature (25°-30°C): (m)

Dynes/cm² x 10^{-10}	2.92
Density, gm/cc	1.56

TNT (Trinitrotoluene)

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	0.06
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:

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

Explosion Temperature versus TNT Initial Temperature:

TNT Temperature, Initial	Explosion Temperature, °C
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:

°C	State	gm/cc
27 to 70	Flaked	1.65
80	Flaked	1.64
82	Liquid	1.48
87	Liquid	1.48
95	Liquid	1.47

Solubility of TNT, gm/100 gm (%), in: (f)

Water °C	Water %	Acetone °C	Acetone %	Benzene °C	Benzene %	Toluene °C	Toluene %
0	0.0100	0	57	0	13	0	28
20	0.0130	20	109	20	67	20	55
40	0.0285	40	228	40	180	40	130
60	0.0675	60	600	60	478	60	367
				80	>2000	80	>1700

Carbon tetrachloride °C	Carbon tetrachloride %	Ether °C	Ether %	Chloroform °C	Chloroform %	Trichloro-ethylene °C	Trichloro-ethylene %
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						

TNT (Trinitrotoluene)

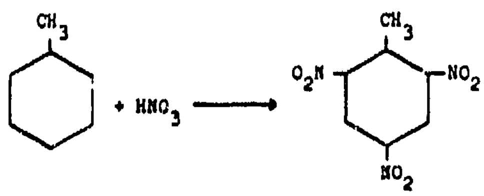
Pyridine °C	%	Methyl acetate °C	%	Ethylene dichloride °C	%	β-Ethoxy-ethyl-acetate °C	%
20	140	20	73	20	34	20	29.5
40	250	40	135	40	123	40	49
60	640	50	280	60	460	50	96
70	1250						

Tetrachloro-ethane °C	%	Aniline °C	%	Isopropyl alcohol °C	%	Ethanol °C	%
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

Isobutyl alcohol °C	%	Carbon disulfide °C	%	Chlorobenzene °C	%
0	0.20	0	0.14	20	35
20	0.61	20	0.44	30	51
40	1.41	40	1.4	40	79
50	2.35			50	116

Preparation:

(AC 7258, 7259, 7260 - Nitration Kinetics)
(Chemistry of Powder and Explosives, Davis)



In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than 6¢/lb. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also counter current, MNB was nitrated to TNT.

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion (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:

$$\frac{d\,(TNT)}{dt} = K\,(NO_2^+)\,\left[K'\,(HSO_4^-) + K''\,(H_2SO_4)\right]\,(DNT)$$

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 Housermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 1006; 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 ($Na_2S \cdot 9H_2O$) in 6 parts of water.

References:[75]

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

[75] See footnote 1, page 10.

(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, NDRC, 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) Mastrov, 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	709
1120	1041	1192	743	1224	975	1146	817	1098	739
1140	1121	1272	853	1284	1145	1276	837	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	1414	1315	1556	1307	1228	1099
1460	1651	1452	1243	1444	1395	1636	1417	1238	1109
1500	1821	1472	1323	1454	1425	1756	1427	1308	1129

TNT (Trinitrotoluene)

0	2	3	4	5	6	7	8	9
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

Composition:	
%	
RDX	42
TNT	40
Aluminum	18
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	42
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	9
Sample Wt, mg	15
Friction Pendulum Test:	
Steel Shoe	
Fiber Shoe	
Rifle Bullet Impact Test: Trials	
	%
Explosions	20
Partials	80
Burned	0
Unaffected	0
Explosion Temperature:	°C
Seconds, 0.1 (no cap used)	
1	
5 Decomposes	260
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
100°C Heat Test:	
% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.10
Explosion in 100 Hrs	None
Flammability Index:	196
Hygroscopicity: % 30°C, 90% RH	0.00
Volatility:	

Molecular Weight:	97
Oxygen Balance:	
CO_2 %	-55
CO %	-26
Density: gm/cc Cast	1.76-1.81
Melting Point: °C	
Freezing Point: °C	
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	
120°C	1.0
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	59.5
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	0.18
Lead Azide	
Tetryl	
Ballistic Mortar, % TNT: (a)	138
Trauzl Test, % TNT: (b)	164
Plate Dent Test: (c)	
Method	B
Condition	Cast
Confined	No
Density, gm/cc	1.83
Brisance, % TNT	120
Detonation Rate: (d)	
Confinement	None
Condition	Cast
Charge Diameter, in.	1.0
Density, gm/cc	1.81
Rate, meters/second	7495

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

Heat of:	(a)	
Combustion, cal/gm		3740
Explosion, cal/gm		1800
Gas Volume, cc/gm		
Formation, cal/gm		
Fusion, cal/gm		

Specific Heat: cal/gm/°C	(b)	
At -5°C		0.22
Density, gm/cc		1.82
At 15°C		0.24

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, Mohs' Scale:

Young's Modulus:	(b)	
E', dynes/cm²		9.53×10^{10}
E, lb/inch²		1.38×10^{6}
Density, gm/cc		1.77

Compressive Strength: lb/inch²	(b)	2100-2300
Density, gm/cc		1.77

Vapor Pressure:
°C mm Mercury

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

Armor Plate Impact Test:

60 mm Mortar Projectile:	(a)
50% Inert, Velocity, ft/sec	185
Aluminum Fineness	

500-lb General Purpose Bombs:

Plate Thickness, inches

1
1¼
1½
1¾

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

Fragmentation Test:

90 mm HE, M71 Projectile, Lot WC-91:

Density, gm/cc	1.75
Charge Wt, lb	2.316

Total No. of Fragments:

For TNT	703
For Subject HE	891

3 inch HE, M42A1 Projectile, Lot KC-5:

Density, gm/cc	1.79
Charge Wt, lb	0.940

Total No. of Fragments:

For TNT	514
For Subject HE	647

Fragment Velocity: ft/sec

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	

Shaped Charge Effectiveness, TNT = 100:
50/36.5/13.5

	Glass Cones	Steel Cones
Hole Volume	150	145
Hole Depth	127	131

Color: Gray

Principal Uses: Depth charges, bombs

Method of Loading: Cast

Loading Density: gm/cc 1.76-1.81

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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

Torpex

Preparation:

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:

	Torpex 2 unwaxed (a)	Torpex 2 waxed (b)	Torpex 3 (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 HBX and Tritonal, OSRD No. 5406, 31 July 1945.

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

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

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

[76] See footnote 1, page 10.

(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.

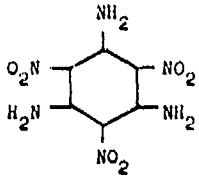
(g) Also see the following Picatinny Arsenal Technical Reports on Torpex:

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

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



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	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds, 0.1 (no cap used)	
1	
5	
10	
15	
20	

75°C International Heat Test:

% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	0.00
% Loss, 2nd 48 Hrs	0.00
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: ($C_6H_6N_6O_6$) 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}

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

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.30
Tetryl	----

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:

- Method
- Condition
- Confined
- Density, gm/cc
- Brisance, % TNT

Detonation Rate:

Confinement	None
Condition	Pressed
Charge Diameter, in.	0.5
Density, gm/cc	1.80
Rate, meters/second	7500

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

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)

Density, gm/cc	Meters/sec
1.290	5380
1.345	5628
1.675	6550
1.675	6575
1.882	7035
1.835	7220

Heat of:

Explosion, cal/gm 2831

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 85% yield. The crude nitration product was aminated in benzene with ammonia gas to TATNB, in yields of at least 95%.

Origin:

TATNB was prepared for the first time in 1888 by C. L. Jackson and J. 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.

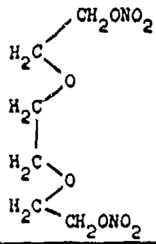
(c) E. M. Fisher and E. A. Christian, Explosion Effects Data Sheets, NAVORD Report No. 2986, 14 June 1955.

[77] See footnote 1, page 10.

Triethylene Glycol Dinitrate (TEGN) Liquid

Composition:

%	
C	29.9
H	5.4
N	11.7
O	53.0
C/H Ratio	0.177



Molecular Weight: $(C_6H_{12}N_2O_8)$ 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

Boiling Point: °C

Refractive Index,

n [illegible]	1.4540
n [illegible]	
n [illegible]	

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	100+
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	43
Sample Wt, mg	

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		

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

200 Gram Bomb Sand Test:

Sand, gm	14.7

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

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	1.8
% Loss, 2nd 48 Hrs	1.6
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility: 60°C, mg/cm^2/hr 40

Detonation Rate:

Confinement	[illegible] steel
Condition	Liquid
Charge Diameter, in.	1.25
Density, gm/cc	1.33
Rate, meters/second	Fails

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

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

Heat of:

Combustion, cal/gm	3428
Explosion, cal/gm	357
Gas Volume, cc/gm	851

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color:

Principal Uses: Ingredient of rocket and double base propellants

Method of Loading:

Loading Density: gm/cc

Storage:

Method	Liquid
Hazard Class (Quantity-Distance)	
Compatibility Group	
Exudation	

Solubility in Water, gm/100 gm, at:

25°C	0.55
60°C	0.68

Solubility, gm/100 gm, at 25°C, in:

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

Vapor Pressure:

°C	mm Mercury
25	<0.001

Triethylene Glycol Dinitrate (TEGN) Liquid

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 $(H_2OOC \cdot CH_2 \cdot O\text{-}CH_2)_2$ (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 Vigeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at 0 ± 5°C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at 0 ± 5°C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ice and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The 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:

3	5	6	7	8
1953	1745	1786	1767	1638
2193		2056	1817	

[78] See footnote 1, page 10.

Trimonite

Composition:			
%			
Picric Acid	88	-	
Mononitronaphthalene	12	10	
C/H Ratio			
Impact Sensitivity, 2 Kg Wt:			
Bureau of Mines Apparatus, cm		60	
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.		10	
Sample Wt, mg			
Friction Pendulum Test:			
Steel Shoe			
Fiber Shoe			
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	315		
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			
Flammability Index:			
Hygroscopicity: %			
Volatility:			

Molecular Weight:		217
Oxygen Balance:		
CO_2 %		-62
CO %		-14
Density: gm/cc	Cast	1.60
Melting Point: °C		90
Freezing Point: °C		
Boiling Point: °C	Explodes	300
Refractive Index, n_{20}^{D}		
n_{25}^{D}		
n_{30}^{D}		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		0.9
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand, gm		44.2
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		
Lead Azide		0.20
Tetryl		0.04
Ballistic Mortar, % TNT:		
Trauzl Test, % TNT:		
Plate Dent Test:		
Method		
Condition		
Confined		
Density, gm/cc		
Brisance, % TNT		
Detonation Rate:		
Confinement		None
Condition		Cast
Charge Diameter, in.		1.0
Density, gm/cc		1.60
Rate, meters/second		7020

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:

Principal Uses: TNT substitute in projectiles and bombs

Method of Loading: Cast

Loading Density: gm/cc 1.60

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	Exudes at 50°C

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.

Trimonite

Origin:

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]

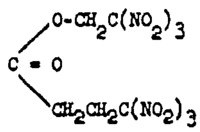
(a) See the following Picatinny Arsenal Technical Reports on Trimonite:

2	5	6	8
1352	1325	926	1098
1372		976	1838

[79] See footnote 1, page 10.

Composition:

%	
C	18.6
H	1.6
N	21.8
O	58.0



C/H Ratio 0.202

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

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 50% point (Alhot bar) (a)	225
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

Flammability Index:

Hygroscopicity: %

30°C, 90% RH	0.00
75°C, 5 months	Nil (a)

Volatility:

Molecular Weight: $(C_6H_5N_6O_{14})$ 386

Oxygen Balance:

CO_2 %	-4.2
CO %	20.8

Density: gm/cc Form I 1.78

Melting Point: °C 93

Freezing Point: °C

Boiling Point: °C

Refractive Index, n_D^{25} Form I (e)

Crystal Axis	
α	1.518
β	1.527
γ	1.546

Vacuum Stability Test:

cc/40 Hrs, at

90°C		----
100°C	48 hrs	0.60
120°C		
135°C		
150°C		

200 Gram Bomb Sand Test:

Sand, gm

Sensitivity to Initiation:

Minimum Detonating Charge, gm

Mercury Fulminate

Lead Azide

Tetryl

Ballistic Mortar, % TNT: (b) 136

Trauzl Test, % TNT:

Plate Dent Test:

Method

Condition

Confined

Density, gm/cc

Brisance, % TNT

Detonation Rate:

Confinement		
Condition		
Charge Diameter, in.		
Density, gm/cc	1.60	1.76
Rate, meters/second	7760	8290

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

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

Specific Heat: cal/gm/°C

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: (e)

°C	mm Mercury
65	3.3×10^{-4}
75	1.3×10^{-4}
85	4.2×10^{-4}
100	2.3×10^{-3}
120	1.4×10^{-2}

Decomposition Equation:

Oxygen, atoms/sec (Z/sec)	4.4×10^{21}
Heat, kilocalorie/mole (ΔH, kcal/mol)	43.4
Temperature Range, °C	
Phase	Liquid

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

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

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 H-6):

	Sphere		Cylinder (h)	
Air: 1-lb Charge:	EW*	EV*	EW*	EV*
Peak Pressure	0.91	0.84	0.81	0.75
Impulse	0.73	0.67	0.74	0.69
Energy				

Air, Confined:

Impulse

Under Water:

Peak Pressure

Impulse

Energy

Underground:

Peak Pressure

Impulse

Energy

*EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Colorless

Principal Uses:

Method of Loading:

Loading Density: gm/cc

Form I	1.783
Form II	1.677
Liquid, 99°C,	1.551

Storage:

Method: Wet

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation

Bruceton Safety Test Results: (g)

Mean and standard deviation of lengths of 0.300 diameter cylinder across which initiation is possible for 50% certainty:

TNT	0.391	± 0.040
RDX Comp B	0.381	± 0.042
TNETB	0.920	± 0.059

Absolute Viscosity, poises: (e)

Temp, 98.9°C	0.173
106.5°C	0.138

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
BTNES (bis(trinitroethyl) succinate)	80+
BTNEN (bis(trinitroethyl) nitramine)	68.5
TNB (trinitrobenzene)	65
Compound A ($C_4H_6N_4O_7$ formed by condensation of 1,1-dinitroethane)	77
Trinitroethyl trinitrobenzoate (27%)	80.5 (f)

Crystallographic Data: (a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°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: (d)

$(NO_2)_3CCH_2CH_2COCl$ + $(NO_2)_3CH_2OH$ —H_2SO_4→

trinitrobutyryl chloride + trinitroethanol (sulfuric acid)

$(NO_2)_3CCH_2CH_2COOCH_2C(NO_2)_3$ + HCl

2,2,2-trinitroethyl-4,4,4-trinitrobutyrate + hydrochloric acid

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.

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. Svadeba, 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.

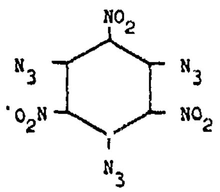
(h) R. W. Gipson, Sensitivity of Explosives, IV Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

[80]See footnote 1, page 10.

Trinitro Triazidobenzene

Composition:

%	
C	21.4
N	50.0
O	28.6



C/H Ratio

Impact Sensitivity, 2 Kg Wt:
Bureau of Mines Apparatus, cm (a) ≤ 25
Sample Wt 20 mg
Picatinny Arsenal Apparatus, in.
Sample Wt, mg

Friction Pendulum Test:
Steel Shoe
Fiber Shoe

Rifle Bullet Impact Test: Trials

%
Explosions
Partials
Burned
Unaffected

Explosion Temperature: °C (a)

	°C
Seconds, 0.1 (no cap used)	--
1	--
5	150
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

Flammability Index:

Hygroscopicity: % 30°C, 90% RH 0.00

Volatility:

Molecular Weight: ($C_6O_6N_{12}$) 336

Oxygen Balance:
CO_2 % -29
CO % 0.0

Density: gm/cc Crystal 1.81

Melting Point: °C Decomposes 131

Freezing Point: °C

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
120°C
135°C
150°C

200 Gram Bomb Sand Test:
Sand, gm

Sensitivity to Initiation:
Minimum Detonating Charge, gm
Mercury Fulminate
Lead Azide
Tetryl

Ballistic Mortar, % TNT:

Trauzl Test, % PETN: 90

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:
Confinement
Condition
Charge Diameter, in.
Density, gm/cc
Rate, meters/second

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: Greenish-yellow

Principal Uses: (c) Ingredient of primer mix

Method of Loading: Pressed
Dead presses at about 42,000 psi

Loading Density: gm/cc
At 42,000 psi 1.75

Storage:

Method

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation None

Qualitative Solubilities at Room Temperature:

Solvent	Solubility
Acetone	Readily soluble
Chloroform	Moderately soluble
Alcohol	Sparingly soluble
Water	Insoluble

Compatibility with Metals:

Wet: Does not attack iron, steel, copper or brass.

Heat of:

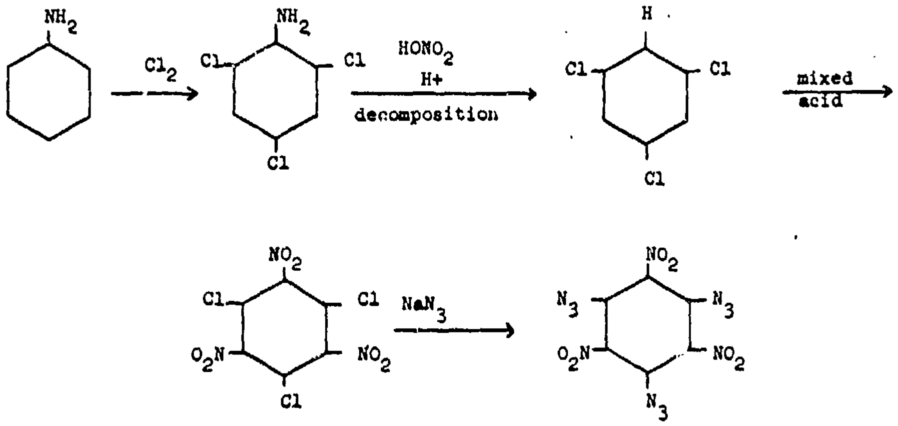
Combustion, cal/gm (a) 2554

Burning Rate: (b)

cm/sec 0.65

Trinitro Triazidobenzene

Preparation: (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).

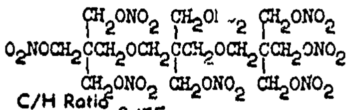
(e) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.

(f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

[81]See footnote 1, page 10.

Composition:

%	
C	24.6
H	3.3
N	15.3
O	56.8



C/H Ratio 0.175

Impact Sensitivity, 2 Kg Wt:

Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	9
Sample Wt, mg	24

Friction Pendulum Test:

Steel Shoe	Unaffected
Fiber Shoe	Unaffected

Rifle Bullet Impact Test: Trials

	%
Explosions	
Partials	
Burned	
Unaffected	

Explosion Temperature: °C

Seconds	°C
0.1 (no cap used)	---
1	---
5	225
10	
15	
20	

75°C International Heat Test:
% Loss in 48 Hrs

100°C Heat Test:

% Loss, 1st 48 Hrs	1.15
% Loss, 2nd 48 Hrs	0.75
Explosion in 100 Hrs	None

Flammability Index:

Hygroscopicity: %

Volatility:

Molecular Weight: ($C_{15}H_{24}N_8O_{26}$) 732

Oxygen Balance:

CO_2 %	-35
CO %	-2.2

Density: gm/cc Crystal 1.58

Melting Point: °C 82 to 84

Freezing Point: °C

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	Pure	2.45
120°C	Specially purified	1.94
135°C		
150°C		

200 Gram Bomb Sand Test:
Sand, gm 58.9

Sensitivity to Initiation:

Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.30
Tetryl	----

Ballistic Mortar, % TNT:

Trauzl Test, % TNT:

Plate Dent Test:
Method
Condition
Confined
Density, gm/cc
Brisance, % TNT

Detonation Rate:

Confinement	None
Condition	Pressed
Charge Diameter, in.	0.5
Density, gm/cc	1.56
Rate, meters/second	7650

Tripentaerythritol Octanitrate (TPEON)

Booster Sensitivity Test:
Condition
Tetryl, gm
Wax, in. for 50% Detonation
Wax, gm
Density, gm/cc

Heat of:

Combustion, cal/gm	2632
Explosion, cal/gm	1085
Gas Volume, cc/gm	762
Formation, cal/gm	
Fusion, cal/gm	

Specific Heat: cal/gm/°C

Specific Impulse:

lb-sec/lb (calculated)	240

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

Decomposition Equation:

Oxygen, atoms/sec (Z/sec)	
Heat, kilocalorie/mole (ΔH, kcal/mol)	23.1
Temperature Range, °C	215 to 250
Phase	Liquid

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

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

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: 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

Storage:

Method: Dry

Hazard Class (Quantity-Distance)

Compatibility Group

Exudation: None

Hygroscopicity, Gain or Loss in Wt, %:

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

Solubility:

Solvent	Solubility
Water	Insoluble
Alcohol	Soluble
Chloroform	Soluble
Acetone, hot	Very soluble
Benzene, hot	Very soluble

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).

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.

[82]See footnote 1, page 10.

Tritonal, 80/20

Composition: %		**Molecular Weight:**	81
TNT	80	**Oxygen Balance:**	
Aluminum	20	CO_2 %	-77
		CO %	-38
		Density: gm/cc Cast	1.72
		Melting Point: °C	
C/H Ratio		**Freezing Point:** °C	
Impact Sensitivity, 2 Kg Wt:		**Boiling Point:** °C	
Bureau of Mines Apparatus, cm	85	**Refractive Index,** n_D^{20}	
Sample Wt 20 mg		n_D^{25}	
Picatinny Arsenal Apparatus, in.	13	n_D^{30}	
Sample Wt, mg	16		
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	0.1
	%	120°C	0.2
Explosions	60	135°C	--
Partials	0	150°C	0.8
Burned	0	**200 Gram Bomb Sand Test:**	
Unaffected	40	Sand, gm	
Explosion Temperature:	°C	**Sensitivity to Initiation:**	
Seconds, 0.1 (no cap used)	610	Minimum Detonating Charge, gm	
1	520	Mercury Fulminate	
5 Decomposes	470	Lead Azide	0.20
10	465	Tetryl	0.10
15		**Ballistic Mortar, % TNT:** (a)	124
20		**Trauzl Test, % TNT:** (b)	125
75°C International Heat Test:		**Plate Dent Test:** (c)	
% Loss in 48 Hrs		Method	B
100°C Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs		Confined	No
% Loss, 2nd 48 Hrs		Density, gm/cc	1.75
Explosion in 100 Hrs		Brisance, % TNT	93
Flammability Index:	100	**Detonation Rate:**	
		Confinement	None / None
Hygroscopicity: % 30°C, 90% RH	0.00	Condition	Cast / Pressed
		Charge Diameter, in.	1.0 / 1.0
Volatility:		Density, gm/cc	1.71 / 1.72
		Rate, meters/second	6475 / 6700

Booster Sensitivity Test: (d)

Condition	Cast
Tetryl, gm	100
Wax, in. for 50% Detonation	0.58
Wax, gm	
Density, gm/cc	1.75

Heat of: (c)

Combustion, cal/gm	4480
Explosion, cal/gm	1770
Gas Volume, cc/gm	
Formation, cal/gm	
Fusion, cal/gm	

Specific Heat: cal/gm/°C (b)

At -5°C	0.23
Density, gm/cc	1.74
At 20°C	0.31

Burning Rate:
cm/sec

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

Decomposition Equation:
Oxygen, atoms/sec
(Z/sec)
Heat, kilocalorie/mole
(ΔH, kcal/mol)
Temperature Range, °C
Phase

Armor Plate Impact Test: (e)

60 mm Mortar Projectile:

50% Inert, Velocity, ft/sec	509	>1100
Aluminum Fineness	100	12

500-lb General Purpose Bombs:

Plate Thickness, inches	Trials	% Inert
1	0	
1¼	6	100
1½	6	33
1¾	0	

Bomb Drop Test: (e)

T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:

Max Safe Drop, ft

500-lb General Purpose Bomb vs Concrete:

	Seal	Seal
Height, ft	4,000	5,000
Trials	34	14
Unaffected	32	14
Low Order	0	0
High Order	2	0

1000-lb General Purpose Bomb vs Concrete:

	Seal
Height, ft	5,000
Trials	24
Unaffected	23
Low Order	0
High Order	1

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-5:

Density, gm/cc	1.73
Charge Wt, lb	0.914
Total No. of Fragments:	
For TNT	514
For Subject HE	485

Fragment Velocity: ft/sec

At 9 ft	2460
At 25½ ft	2380
Density, gm/cc	1.72

Blast (Relative to TNT): (%)

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

Shaped Charge Effectiveness, TNT = 100:

	Glass Cones	Steel Cones
Hole Volume		
Hole Depth		

Color: Gray

Principal Uses: GP bombs

Method of Loading: Cast

Loading Density: gm/cc 1.65-1.72

Storage:

Method	Dry
Hazard Class (Quantity-Distance)	Class 9
Compatibility Group	Group I
Exudation	

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

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).

[83]See footnote 1, page 10.

Tritonal, 80/20

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

0	3	4	5	6	7	8
1530	1693	1444	1635	1956	1737	2138
1560	2353				2127	
2010						

Composition:	
%	
HMX	70.0
Nitrocellulose (13.15% N)	15.0
Nitroglycerin	10.7
2-Nitrodiphenylamine	1.3
Triacetin	3.0
C/H Ratio	
Impact Sensitivity, 2 Kg Wt:	
Bureau of Mines Apparatus, cm	
Sample Wt 20 mg	
Picatinny Arsenal Apparatus, in.	
Sample Wt, mg	
Friction Pendulum Test:	
Steel Shoe	Unaffected
Fiber Shoe	Unaffected
Rifle Bullet Impact Test: Trials	
%	
Explosions	
Partials	
Burned	
Unaffected	
Explosion Temperature: °C	
Seconds, 0.1 (no cap used)	
1	
5	
10	
15	
20	
75°C International Heat Test:	
% Loss in 48 Hrs	
90°C Heat Test:	
% Loss, 1st 48 Hrs	0.28
% Loss, 2nd 48 Hrs	1.12
Explosion in 100 Hrs	None
Flammability Index:	
Hygroscopicity: %	
Volatility:	

Molecular Weight:	281
Oxygen Balance:	
CO_2 %	-26
CO %	-0.5
Density: gm/cc Pressed	1.72
Melting Point: °C	
Freezing Point: °C	
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	1.29
120°C 29 hours	11+
135°C	
150°C	
200 Gram Bomb Sand Test:	
Sand, gm	66.4
Sensitivity to Initiation:	
Minimum Detonating Charge, gm	
Mercury Fulminate	----
Lead Azide	0.30
Tetryl	----
Ballistic Mortar, % TNT:	
Trauzl 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 (calculated)	8500

*See footnote on following page.

Valtex No. 448*

Booster Sensitivity Test:	
Condition	
Tetryl, gm	
Wax, in. for 50% Detonation	
Wax, gm	
Density, gm/cc	
Heat of:	
Combustion, cal/gm	2359
Explosion, cal/gm	1226
Gas Volume, cc/gm	
Formation, cal/gm	
Fusion, cal/gm	
Compression at Rupture: %	8.26
Work to Produce Rupture: ft-lb/inch^3	9.62
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	0.24×10^{10}
E, lb/inch²	0.35×10^{5}
Density, gm/cc	
Compressive Strength: lb/inch²	2720
Vapor Pressure: °C mm Mercury	

*Name assigned by Dr. Mark M. Jones, formerly of PA; based on original development by James H. Veltman.

Decomposition Equation:	
Oxygen, atoms/sec (Z/sec)	
Heat, kilocalorie/mole (ΔH, kcal/mol)	
Temperature Range, °C	
Phase	
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	
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	

Fragmentation Test:	**Shaped Charge Effectiveness, TNT = 100:**
90 mm HE, M71 Projectile, Lot WC-91:	Glass Cones Steel Cones
Density, gm/cc	Hole Volume
Charge Wt, lb	Hole Depth
Total No. of Fragments:	**Color:** Orange
For TNT	
For Subject HE	**Principal Uses:** High mechanical strength machinable explosive
3 inch HE, M42A1 Projectile, Lot KC-5:	
Density, gm/cc	
Charge Wt, lb	
Total No. of Fragments:	**Method of Loading:** Pressed
For TNT	
For Subject HE	
Fragment Velocity: ft/sec	**Loading Density:** gm/cc
At 9 ft	At 6,700 psi 1.72
At 25½ ft	
Density, gm/cc	**Storage:**
Blast (Relative to TNT):	Method Dry
Air:	Hazard Class (Quantity-Distance)
Peak Pressure	Compatibility Group
Impulse	Exudation None
Energy	Machinability Excellent
Air, Confined:	
Impulse	
Under Water:	
Peak Pressure	
Impulse	
Energy	
Underground:	
Peak Pressure	
Impulse	
Energy	

Veltex No. 448

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agitator. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Raise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The HMX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture content between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished 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 determinate the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding 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.

[84]See footnote 1, page 10.

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