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# ENGINEERING DESIGN HANDBOOK

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## EXPLOSIVES SERIES PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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HEADQUARTERS  
 UNITED STATES ARMY MATERIEL COMMAND  
 WASHINGTON, D. C. 20315

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 No. 706-177\*

29 January 1971

ENGINEERING DESIGN HANDBOOK  
 PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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\*This pamphlet supersedes AMCP 706-177, 22 March 1967, including Change 1.  
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## PREFACE

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

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

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

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

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

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

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

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

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

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

Commanding General  
U. S. Army Materiel Command  
ATTN: AMCRD-TV  
Washington, D. C. 20315

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

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

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

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

## 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 societe'chimique de France.
CA	Chemical Abstracts.
calc	calculated.
Chem Met Eng	Chemical and Metallurgical Engineering.
Chim et Ind	Chimie et Industrie.
Comp rend	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
cp	centipoise.
CR	Comptes rendus hebdomadaires des seances de l'Academie des Sciences (Paris).
dec	decomposes.
AH	difference in heat (i.e., heat evolved) by decomposition.
DRP	Deutsches Reichspatent.
E	modulus of elasticity or "Young's modulus"; longitudinal stress/change in length; (force/area)/(elongation/length); expressed in lb/inch <sup>2</sup> .
E'	same as E, but expressed in dynes/cm <sup>2</sup> .
Gazz chim ital	Gazzetta Chimica Italiana.
GP	general purpose.
HE	high explosive.
HEAT	high explosive antitank.
Ind Eng Chem	Industrial & Engineering Chemistry.
J Am Chem Soc	Journal of the American Chemical Society
J Chem Ind	The Journal of the Society of Chemical Industry (London).
J Chem Soc	Journal of the Chemical Society (London).
J Frank Inst	Journal of the Franklin Institute.
J 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.
Mem poudr	Monatshefte für Chemie (Wein).
mg	Mémorial des poudres et salpêtres (Paris). milligram.

## ABBREVIATIONS AND SYMBOLS (cont'd)

min	minimum.
ml	milliliter.
m/s	meters per second.
MW	molecular weight.
NAVORD	Bureau of Ordnance (U. S. Navy)
NC	nitrocellulose.
$n_D^{20}$	index of refraction, with D band of sodium as light source, at twenty degrees centigrade.
NDRC	National Defense Research Committee.
NFOC	National Fireworks Ordnance Corporation.
NG	nitroglycerin.
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 Sprengstoff- wesen (München).
Z/sec	atoms of oxygen per second.



# PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

## INTRODUCTION

1. PREDOMINANTLY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Rather, the main resource has been reports from facilities using standard or well-known test procedures.
2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of explosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.
3. SCOPE. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.
4. REFERENCE NOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given explosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain additional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract RAI-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

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

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

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

The 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."

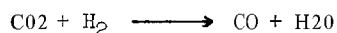
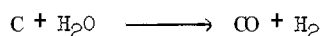
The molecular weight (MW) of a mixture can be calculated from the equation

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

where a, b, c and n are the weight percents of the components, and  $\text{mw}_1$ ,  $\text{mw}_2$ ,  $\text{mw}_3$  and  $\text{mw}_n$  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:



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

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

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

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

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

(14) "Density."

(15) "Melting Point."

(16) "Freezing Point."

(17) "Boiling Point."

(18) "Refractive Index."

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

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

(20) "200 Gram Bomb Sand Test."

(a) Sand test for solids. (a)

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

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." (c)

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 boosted by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.

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

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

(25) "Detonation Rate." (g)

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

b. Second tabular page.

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

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast 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, boosted by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated cone) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The cones used are commercial Pyrex glass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch wall thickness.

Unconfined charges 1.63 inches in diameter and 6 inches long are tested at a standoff of 1.63 inches against stacks of 4 x 4 x 1 inch mild steel plates. 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-weighted 250-cc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electrometric pH method.

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

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

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

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

(7) Destruction by chemical decomposition.

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

(8) Other information.

(9) References.

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

a. W. H. Rinkenbach and A. J. Clear, Standard Laboratory Procedures for Sensitivity, Brisance, and Stability of Explosives, PAIR No. 1401, 18 March 1944, Revised 28 February 1950.

b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Nitroglycerin and Other Liquid Explosives, PAIR 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, PAIR No. 1465, 4 July 1945.

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

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

j. Report AC-2983/Org Expl 179.

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

k. Eastern Laboratory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

1. 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, PAIR 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.

Composition: %  Ammonium Nitrate                      80 TNT    20  C/H Ratio	Molecular Weight:	92	
	Oxygen Balance: CO, %	+1	
	CO %	+11	
	Density: gm/cc                      Cast	1.46	
	Melting Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm      90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.    15 Sample Wt, mg                            17	Freezing Point: °C		
	Boiling Point: °C		
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>		
Friction Pendulum Test: Steel Shoe                            Unaffected Fiber Shoe                            Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C		
Rifle Bullet Impact Test: 5 Trials  Explosions                            0 Partials                                0 Burned                                 0 Unaffected                            100	100°C	0.45	
	120°C	0.95	
	135°C		
	150°C	6.8	
Explosion Temperature:           °C Seconds, 0.1 (no cap used) 1 5 kcomposes 280 10 15 20	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	
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	Trauzl Test, % TNT: (b)	123	
	Plate Dent Test: Method		
	Condition		
	Confined		
Flammability Index:	Density, gm/cc		
	Brisance, % TNT		
Hygroscopicity: % 30°C, 90%RH, 2 days              61	Detonation Rate:		
	Confinement	None	None
Volatility:                            Ni 1	Condition	Cast	Cast
	Charge Diameter, in.	1.0	1.0
	Density, gm/cc	1.46	1.50
	Rate, meters/second	4500	5100

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth
<b>Fragment Velocity: ft/sec</b> (f) At 9 ft    1900 At 25½ ft     1750 Density, gm/cc	<b>Color:</b> Buff-yellow
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy	<b>Principal Uses:</b> Bombs, HE projectiles
	<b>Method of Loading:</b> Cast
	<b>Loading Density: gm/cc</b> 1.46
	<b>Storage:</b>  Method    Dry  Hazard Class (Quantity-Distance)                  Class 9  Compatibility Group    Group I  Exudation    Does not exude at 65°C
	<b>Booster Sensitivity Test:</b> (a)  Condition    Pressed Tetryl, gm    100 Wax, in. for 50% Detonation    0.83 Density, gm/cc    1.65  <b>Heat of:</b> (d, e)  Combustion, cal/gm    1002* Explosion, cal/gm    490* Gas Volume, cc/gm    930*  *Calculated from composition of mixture.

Composition: %  Ammonium Nitrate      €0 TNT                              40  C/H Ratio	Molecular Weight:	108
	Oxygen Balance:	
	CO, %	-18
	CO %	+ 2
	Density: gm/cc              Cast	1.60
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm      95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.      16 Sample Wt, mg                              17	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$ $n_{50}^D$	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test:	
Rifle Bullet Impact Test:      Trials %  Explosions Partials Burned Unaffected	cc/40 Hrs, at	
	90°C	
	100°C	
	120°C	
	135°C	
	150°C	
	200 Gram Bomb Sand Test:	
	Sand, gm	41.5
Explosion Temperature:              °C Seconds, 0.1 (no cap used) 1 5      Decomposes 270 10 15 20	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
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:                              Ni 1		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>  Density, gm/cc 1.49  Charge Wt, lb 1.971</p> <p><b>Total No. of Fragments:</b>  For TNT 703  For Subject HE 583</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>  Density, gm/cc 1.57  Charge Wt, lb 0.827</p> <p><b>Total No. of Fragments:</b>  For TNT 514  For Subject HE 408</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume  Hole Depth</p>
<p><b>Fragment Velocity: ft/sec</b>  At 9 ft  At 25½ ft  Density, gm/cc</p>	<p><b>Color:</b> Buff-yellow</p> <p><b>Principal Uses:</b> Bombs, HE projectiles</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>  Peak Pressure 95  Impulse 85  Energy 84</p> <p><b>Air, Confined:</b>  Impulse</p> <p><b>Under Water:</b>  Peak Pressure  Impulse  Energy</p> <p><b>Underground:</b>  Peak Pressure  Impulse  Energy</p>	<p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density: gm/cc</b> 160</p> <p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Does not exude at 65°C</p>
	<p><b>Heat of:</b> (d, e)</p> <p>Combustion, cal/gm 1658*  Explosion, cal/gm 633*  Gas Volume, cc/gm 880*</p> <p>*Calculated from composition of mixture.</p>

Composition: %  Ammonium Nitrate                      50 TNT    50  C/H Ratio	Molecular Weight:                      118	
	Oxygen Balance: CO, %    -27 CO %    - 3	
	Density: gm/cc                      Cast                      1.59	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm                      95 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.                      16 Sample Wt, mg    17	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    0.2 120°C    1.0 135°C 150°C	
Friction Pendulum Test: Steel Shoe    Unaffected Fiber Shoe    Unaffected	200 Gram Bomb Sand Test: Sand, gm    42.5	
Rifle Bullet Impact Test:                      Trials  Explosions    0 Partial    0 Burned    0 Unaffected    100	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide    0.20 Tetryl    0.05	
	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	Ballistic Mortar, % TNT:                      (a)                      124	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Trouzil Test, % TNT:	
	Plate Dent Test: Method    B Condition    Cast Confined    No Density, gm/cc    1.55 Brisance, % TNT    52	
Flammability Index:	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	
Hygroscopicity: %    Ni 1		
Volatility:		



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>  Density, gm/cc 1.55  Charge Wt, lb 2.053</p> <p><b>Total No. of Fragments:</b>  For TNT 703  For Subject HE 630</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>  Density, gm/cc 1.54  Charge Wt, lb 0.819</p> <p><b>Total No. of Fragments:</b>  For TNT 514  For Subject HE 385</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> <th>(g)</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td>53</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td>69</td> <td></td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> Buff-yellow</p> <p><b>Principal Uses:</b> Bombs, HE projectiles</p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density:</b> gm/cc 1.59</p>		Glass Cones	Steel Cones	(g)	Hole Volume	53			Hole Depth	69		
	Glass Cones	Steel Cones	(g)										
Hole Volume	53												
Hole Depth	69												
<p><b>Fragment Velocity:</b> ft/sec  At 9 ft  At 25½ ft  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Does not exude at 65°C</p>												
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>  Peak Pressure 97  Impulse 87  Energy</p> <p><b>Air, Confined:</b>  Impulse</p> <p><b>Under Water:</b>  Peak Pressure  Impulse  Energy 98</p> <p><b>Underground:</b>  Peak Pressure 104  Impulse 104  Energy 104</p>	<p><b>Booster Sensitivity Test:</b> (a)  Condition Cast  Tetryl, gm 100  Wax in. for 50% Detonation 0.60  Density, gm/cc 1.55</p> <p><b>Heat of:</b> (d, e)  Combustion, cal/gm 1990  Explosion, cal/gm 703*  Gas Volume, cc/gm 855*</p> <p>*Calculated from composition of mixture.</p> <p><b>Specific Heat:</b> cal/gm/°C (i)  Temp, 20° to 80°C 0.383</p> <p><b>Bomb Drop Test:</b>  T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:  Max Safe Drop, ft 4000-5000</p>												

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:<sup>2</sup>

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

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

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

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

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

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

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

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

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
240	681	132	743	364	65	266	1207	548	549
350	731	182	1173	694	425	556	1457	638	799
630	901	1302	1373	734	695	666	1797	838	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.

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

Composition: %  Ammonium Nitrate           22 TNT                           67 Aluminum                   11  C/H Ratio	Molecular Weight:	102
	Oxygen Balance:	
	CO, %	-55
	CO %	-22
	Density: gm/cc	Cast   1.65
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm   91 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. <b>11</b> Sample Wt, mg                       19	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$	
	$n_{30}^D$	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	4.4
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	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate           0.20 Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a)	122
100°C Heat Test: % Loss, 1st 48 Hrs           0.00 % Loss, 2nd 48 Hrs       0.10 Explosion in 100 Hrs       None	Trauzl Test, % TNT:	
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: %	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                      1.65                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                                      655                  For Subject HE                              550</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume                  Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b></p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><u>Preparation:</u>                  Procedure same as described under <u>Amatols</u>, 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.</p>	<p><b>Principal Uses:</b>    Projectile filler</p>
	<p><b>Method of Loading:</b>              Cast</p>
	<p><b>Loading Density:</b> gm/cc      1.65</p>
	<p><b>Storage:</b></p> <p>Method                                      Dry</p> <p>Hazard Class (Quantity-Distance)    Class 9</p> <p>Compatibility Group</p> <p>Exudation</p>
	<p><u>Origin:</u>                  Castable mixture developed in United States during World War I.</p> <p><u>References:</u>                  (a) W. R. Tomlinson, Jr., <u>Physical and Explosive Properties of Military Explosives</u>, PAIR No. 1372, 29 November 1943.</p> <p>(b) Also see the following Picatinny Arsenal Technical Reports on Ammonals: 1108, 1286, 1292, 1308 and 1783.</p>

Composition: % N 35 H 5 O 60 NH <sub>4</sub> NO <sub>3</sub> C/H Ratio	Molecular Weight: (H <sub>4</sub> N <sub>2</sub> O <sub>3</sub> ) 80	
	Oxygen Balance: OO, % +20 CO % +20	
	Density: gm/cc Crystal 1.73	
	Melting Point: °C 170	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 31 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Friction Pendulum test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability test: cc/40 Hrs, at 90°C	
	100°C 0.3 120°C 0.3 135°C 150°C 0.3	
Rifle Bullet Impact test: Trials Explosions 0 Partials 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test: Sand, gm Ni 1	
	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	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25	
	Ballistic Mortar, % TNT: (a) 56	
100°C Heat test: % Loss, 1st 48 Hrs 0.74 % Loss, 2nd 48 Hrs 0.13 Explosion in 100 Hrs None	Irauzi test, % TNT:	
	Plate Dent test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index: Extreme	Detonation Rate: (b) Confinement None Strong Condition Solid Liquid	
	Charge Diameter, in. 1.25 4.5 Density, gm/cc 0.9 1.4 Rate, meters/second 1000 2500	
Hygroscopicity: % 30°C, 90% RH		
Volatility: Decomposes at 210°C		

<p><b>Booster Sensitivity test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Detonation Velocity (Z/sec):</b> (f) 10<sup>13.8</sup> (h) 10<sup>12.3</sup>                  Heat, kilocalorie/mole (AH, kcal/mol) 40.5 38.3                  Temperature Range, °C 243-261 217-267                  Phase Liquid</p>																
<p><b>Heat of:</b>                  Combustion, cal/gm 346                  Explosion, cal/gm 346                  Gas Volume, cc/gm 980                  Formation, cal/gm 1098                  Fusion, cal/gm 18.23</p>	<p><b>Armor Plate Impact test:</b>                  60 mm Mortar Projectile:                  50% Inert, Velocity, ft/sec                  Aluminum Fineness                  500-lb General Purpose Bombs:                  Plate Thickness, inches                  1                  1¼                  1½                  1¾</p>																
<p><b>Specific Heat: cal/gm/°C (e)</b>  <table border="1"> <thead> <tr> <th>°C</th> <th>°C</th> <th>°C</th> <th>°C</th> </tr> </thead> <tbody> <tr> <td>-150</td> <td>0.189</td> <td>0</td> <td>0.397</td> </tr> <tr> <td>-100</td> <td>0.330</td> <td>50</td> <td>0.414</td> </tr> <tr> <td>-50</td> <td>0.364</td> <td>100</td> <td>0.428</td> </tr> </tbody> </table></p>	°C	°C	°C	°C	-150	0.189	0	0.397	-100	0.330	50	0.414	-50	0.364	100	0.428	<p><b>Bomb Drop test:</b>                  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</p>
°C	°C	°C	°C														
-150	0.189	0	0.397														
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<p><b>Burning Rate:</b>                  cm/sec</p>																	
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C 2.9-3.9 x 10<sup>-4</sup></p>																	
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                  Volume, %/°C</p>																	
<p><b>Hardness, Mohs' Scale:</b></p>																	
<p><b>Young's Modulus:</b>                  E, dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>																	
<p><b>Compressive Strength: lb/inch<sup>2</sup></b></p>																	
<p><b>Vapor Pressure: (g)</b>  <table border="1"> <thead> <tr> <th>°C</th> <th>mm Mercury</th> </tr> </thead> <tbody> <tr> <td>188</td> <td>3.25</td> </tr> <tr> <td>205</td> <td>7.45</td> </tr> <tr> <td>216</td> <td>11.55</td> </tr> <tr> <td>223</td> <td>15.80</td> </tr> <tr> <td>237</td> <td>27.0</td> </tr> <tr> <td>249</td> <td>41.0</td> </tr> </tbody> </table></p>	°C	mm Mercury	188	3.25	205	7.45	216	11.55	223	15.80	237	27.0	249	41.0			
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<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> Colorless</p> <p><b>Principal Uses:</b> Explosive ingredient of mixtures used in bombs or large caliber projectiles</p> <p><b>Method of Loading:</b> Pressed or cast depending on composition of mixture</p> <p><b>Loading Density:</b> gm/cc Variable</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth					
	Glass Cones	Steel Cones											
Hole Volume													
Hole Depth													
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 12</td> </tr> <tr> <td>Compatibility Group</td> <td>Group D</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 12	Compatibility Group	Group D	Exudation	None				
Method	Dry												
Hazard Class (Quantity-Distance)	Class 12												
Compatibility Group	Group D												
Exudation	None												
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Effect of Temperature on Impact Sensitivity (Chemically pure grade):</b> (b)</p> <table border="0"> <thead> <tr> <th><u>Temp.</u> <u>°C</u></th> <th><u>PA Impact Test</u> <u>2 Kg Wt. inches</u></th> </tr> </thead> <tbody> <tr> <td>25</td> <td>31</td> </tr> <tr> <td>75</td> <td>28</td> </tr> <tr> <td>100</td> <td>27</td> </tr> <tr> <td>150</td> <td>27</td> </tr> <tr> <td>175</td> <td>12</td> </tr> </tbody> </table> <p><b>Compatibility with Metals:</b> (a) In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium.</p> <p><b>Entropy:</b> (g) cal/mol. at 25°C 36.0</p>	<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt. inches</u>	25	31	75	28	100	27	150	27	175	12
<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt. inches</u>												
25	31												
75	28												
100	27												
150	27												
175	12												

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

<u>Water</u>		<u>Alcohol</u>		<u>Acetic Acid</u>		<u>Nitric Acid</u>		<u>Pyridine</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	118	20	2.5	16.6	0.0	0	45.1	25	~20-25
20	192	40	5	27.0	0.39	15	73.0		
40	297	60	7.5	80.9	5.8	30	106		
60	421	78	10.5	101.0	20.7	75	201		
80	580			120.0	125				
100	871								

Preparation:

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

Origin:

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

Destruction by Chemical Decomposition:

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

References:<sup>3</sup>

- (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. 11, 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.

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



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

<u>0</u>	<u>1</u>	<u>2</u>	3	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
240	681	182	743	364	695	596	907	548	799
350	731	1302	1323	984	1145	666	1117	638	1369
630	1051	1682	1783	1094	1225	676	1947	938	1409
1290	1241		2183	1214	1455	946	2167	1008	
1720	<b>1311</b>			1234	1635	1106		1038	
	1391			1304	1675	1696			
	1431				1725				

Coyorition:  <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">Cl</td> <td style="width: 15%;">30.2</td> <td rowspan="5" style="width: 15%; text-align: center; vertical-align: middle;"><math>NH_4ClO_4</math></td> </tr> <tr> <td>N</td> <td>11.9</td> </tr> <tr> <td>H</td> <td>3.4</td> </tr> <tr> <td>O</td> <td>54.5</td> </tr> <tr> <td colspan="2">C/H Ratio</td> </tr> </table>	Cl	30.2	$NH_4ClO_4$	N	11.9	H	3.4	O	54.5	C/H Ratio		Molecular Weight: $(ClH_4NO_4)$ 117.5
	Cl	30.2		$NH_4ClO_4$								
	N	11.9										
	H	3.4										
	O	54.5										
C/H Ratio												
	Oxygen Balance: CO, % +27.3 CO % +27.3											
	Density: gm/cc 1.95											
	Melting Point: °C											
	Freezing Point: °C											
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 67 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 24 Sample Wt, mg 24	Boiling Point: °C  Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$											
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 Partial 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											
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:  Trauzl Test, % TNT:											
100°C Heat Test: % Loss, 1st 48 Hrs 0.02 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT											
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second											
Hygroscopicity: %												
Volatility :												

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth			
	Glass Cones	Steel Cones							
	Hole Volume								
	Hole Depth								
	<p><b>Color:</b> Colorless</p>								
<p><b>Principal Uses:</b> Explosive ingredient of mixtures used in pyrotechnics and as projectile filler</p>									
<p><b>Method of Loading:</b> Pressed or cast depending on composition of mixture</p>									
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc                      Variable</p>								
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None
	Method	Dry							
	Hazard Class (Quantity-Distance)	Class 9							
	Compatibility Group								
	Exudation	None							
<p><b>Solubility in Water</b> <u>gm/100 cc saturated solution:</u></p> <table> <tr> <td>0°C</td> <td>12</td> </tr> <tr> <td>25°C</td> <td>20</td> </tr> <tr> <td>60°C</td> <td>39</td> </tr> <tr> <td>100°C</td> <td>∞</td> </tr> </table>	0°C	12	25°C	20	60°C	39	100°C	∞	
0°C	12								
25°C	20								
60°C	39								
100°C	∞								
<p><b>Preparation:</b></p> <p>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).</p>									
<p><b>Heat of:</b></p> <table> <tr> <td>Formation, cal/gm</td> <td>665</td> </tr> </table>	Formation, cal/gm	665							
Formation, cal/gm	665								

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: <sup>4</sup>

(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. 11, Longmans, Green and Co., London, 1922, p. 396.

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

<u>a</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>9</u>
100	321	843	354	1095	1726	1049
		1783	604	1725		1969
			854	2205		

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

Composition: %		Molecular Weight:	125
Barium nitrate	67	Oxygen Balance:	
		CO <sub>2</sub> %	-3
TNT	33	CO %	+13
		Density: gm/cc	Cast 2.55
		Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	35	Refractive Index, n <sub>20</sub> <sup>D</sup>	
Sample Wt 20 mg		n <sub>25</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in.	11	n <sub>30</sub> <sup>D</sup>	
Sample Wt, mg	24		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
		100°C	
Rifle Bullet Impact Test: Trials		120°C	
%		135°C	
Explosions		150°C	
Partials		200 Gram Bomb Sand Test:	
Burned		Sand, gm	26.8
Unaffected			
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Ignites	385	Lead Azide	0.20
10		Tetryl	0.10
15		Ballistic Mortar, % TNT:	
20		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test: (a)	73/27
% Loss in 48 Hrs		Method	B
100°C Heat Test:		Condition	Cast
% Loss, 1st 48 Hrs		Confined	Nb
% Loss, 2nd 48 Hrs		Density, gm/cc	2.52
Explosion in 100 Hrs		Brisance, % TNT	61
Flammability Index:		Detonation Rate:	
		Confinement	
		Condition	
Hygroscopicity: %		Charge Diameter, in.	
30°C, 90% RH	0.00	Density, gm/cc	
Volatility:		Rate, meters/second	

<p><b>Booster Sensitivity Test:</b></p> <p>Condition <span style="float:right">Cast</span></p> <p>Tetryl, gm <span style="float:right">100</span></p> <p>Wax, in. for 50% Detonation <span style="float:right">0.32</span></p> <p>Wax, gm <span style="float:right"></span></p> <p>Density, gm/cc <span style="float:right">2.55</span></p>	<p><b>Decomposition Equation:</b></p> <p>Oxygen, atoms/sec (Z/sec)</p> <p>Heat, kilocalorie/mole (AH, kcal/mol)</p> <p>Temperature Range, °C</p> <p>Phase</p>																				
<p><b>Heat of:</b></p> <p>Combustion, cal/gm</p> <p>Explosion, cal/gm</p> <p>Gas Volume, cc/gm</p> <p>Formation, cal/gm</p> <p>Fusion, cal/gm 75/25 Baratol <span style="float:right">2.8 (d)</span></p>	<p><b>Armor Plate Impact Test:</b></p> <p><b>60 mm Mortar Projectile:</b></p> <p>50% Inert, Velocity, ft/sec</p> <p>Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b></p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>																				
<p><b>Specific Heat: cal/gm/°C (d) 75/25 Baratol</b></p> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align:left">°C</th> <th colspan="2" style="text-align:left">°C</th> </tr> </thead> <tbody> <tr> <td>-75</td> <td>0.152</td> <td>75</td> <td>0.280</td> </tr> <tr> <td>0</td> <td>0.147</td> <td>85</td> <td>0.213</td> </tr> <tr> <td>25</td> <td>0.180</td> <td>90</td> <td>0.201</td> </tr> <tr> <td>50</td> <td>0.229</td> <td>100</td> <td>0.171</td> </tr> </tbody> </table>	°C		°C		-75	0.152	75	0.280	0	0.147	85	0.213	25	0.180	90	0.201	50	0.229	100	0.171	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p> <p>Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p><b>1000-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>
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<p><b>Burning Rate:</b></p> <p>cm/sec</p>																					
<p><b>Thermal Conductivity:</b></p> <p>cal/sec/cm/°C</p>																					
<p><b>Coefficient of Expansion:</b></p> <p>Linear, %/°C</p> <p>Volume, %/°C</p>																					
<p><b>Hardness, Mohs' Scale:</b></p>																					
<p><b>Young's Modulus:</b></p> <p>E, dynes/cm<sup>2</sup></p> <p>E, lb/inch<sup>2</sup></p> <p>Density, gm/cc</p>																					
<p><b>Compressive Strength: lb/inch<sup>2</sup></b></p>																					
<p><b>Vapor Pressure:</b></p> <p>°C <span style="float:right">mm Mercury</span></p>																					

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume                  Hole Depth</p> <hr/> <p><b>Color:</b></p> <hr/> <p><b>Principal Uses:</b> Bomb filler</p> <hr/> <p><b>Method of Loading:</b> Cast</p> <hr/> <p><b>Loading Density:</b> gm/cc 2.55</p>
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method <span style="float: right;">Dry</span></p> <p>Hazard Class (Quantity-Distance) <span style="float: right;">Class 9</span></p> <p>Compatibility Group <span style="float: right;">Group I</span></p> <p>Exudation</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><u>Preparation:</u></p> <p>The appropriate weight of barium nitrate heated to about 90°C is added to molten TNT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature.</p> <p><u>Origin:</u></p> <p>Baratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I.</p>

References:<sup>5</sup>

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

(b) L. C. Smith and E. G. 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:

<u>0</u>	<u>3</u>	<u>6</u>	<u>8</u>
2010	1-783	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.

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



Composition: % Barium nitrate      50 TNT                      35 Aluminum              15  C/H Ratio	Molecular Weight:	111
	Oxygen Balance:	
	CO, %	-24
	CO %	- 7
	Density: gm/cc	2.32
	Melting Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm      30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.      12 Sample Wt, mg                              22	Freezing Point: °C	
	Boiling Point: °C	
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test:      Trials % Explosions Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm                                      39.8	
Explosion Temperature:      °C Seconds, 0.1 (no cap used) 1 5 Ignites                      345 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide                                      0.20 Tetryl    0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:      (a)      96	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Trauzl Test, % TNT:	
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: %	Detonation Rate:                      (b)	
Volatility:	Confinement	None
	Condition	Cast
	Charge Diameter, in.	1.0
	Density, gm/cc	2.32
	Rate, meters/second	5450

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth																	
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure impulse Energy</p>	<p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density:</b> gm/cc 232</p> <p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table> <p><u>Preparation:</u> Procedure same as described under Baratonol except aluminum is added to the barium nitrate-TNT molton mixture under agitation until uniformity in comparison is obtained.</p> <p><u>Booster Sensitivity Test:</u></p> <table border="0"> <tr> <td>Condition</td> <td>(c) Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>100</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td>0.86</td> </tr> <tr> <td>Density, gm/cc</td> <td>2.32</td> </tr> </table> <p><u>Heat of:</u></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2099</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1135</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>410</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation		Condition	(c) Cast	Tetryl, gm	100	Wax, in. for 50% Detonation	0.86	Density, gm/cc	2.32	Combustion, cal/gm	2099	Explosion, cal/gm	1135	Gas Volume, cc/gm	410
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(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, PAIR No. 2138, February 1955.

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

Composition: %  Potassium nitrate      74.0  Sulfur                      10.4  Charcoal                    15.6  C/H Ratio	Molecular Weight:	84
	Oxygen Balance:	
	CO, %	-22
	CO %	- 2
	Density: gm/cc	Variable
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm      32 Sample Wt 20 mg Picatinny Arsenal Apparatus, in.      16 Sample Wt, mg                              16	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$	
	$n_{30}^D$	
Friction Pendulum test: Steel Shoe                      Snaps Fiber Shoe                      Unaffected	Vacuum Stability test:	
	cc/40 Hrs, at	
Rifle Bullet Impact test:      Trials  Explosions                      %  Partial  Burned  Unaffected	90°C	
	100°C	0.5
	120°C	0.9
	135°C	
	150°C	
	200 Gram Bomb Sand Test:	
	Sand, gm	8
Explosion Temperature:      °C Seconds, 0.1 (no cap used)      510  1                                      490 5   Ignites                      427  10                                      356  15  20	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
75°C International Heat test:	Plate Dent Test:	
% Loss in 48 Hrs                      0.31	Method	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
Flammability Index:	Detonation Rate:	
	Confinement	
Hygroscopicity: %      26°C, 75% RH      0.75 25°C, 90% RH      1.91 30°C, 90% RH      2.51	Condition	
	Charge Diameter, in.	
	Volatility:	Density, gm/cc
	Rate, meters/second	400

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p>																		
	<p><b>Color:</b> Black</p>																		
	<p><b>Principal Uses:</b> 1. Igniter powder 2. Time rings (fuzes)</p>																		
	<p><b>Method of Loading:</b> 1. Loose (granulated) 2. Pressed</p>																		
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc                      psi × 10<sup>3</sup></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">25</td> <td style="text-align: center;">50</td> <td style="text-align: center;">60</td> <td style="text-align: center;">65</td> <td style="text-align: center;">70</td> <td style="text-align: center;">75</td> </tr> <tr> <td style="text-align: center;">1.74</td> <td style="text-align: center;">1.84</td> <td style="text-align: center;">1.86</td> <td style="text-align: center;">1.87</td> <td style="text-align: center;">1.88</td> <td style="text-align: center;">1.89</td> </tr> </table>	25	50	60	65	70	75	1.74	1.84	1.86	1.87	1.88	1.89						
	25	50	60	65	70	75													
1.74	1.84	1.86	1.87	1.88	1.89														
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><u>Initiating Efficiency:</u></p> <p><u>Grams Required to Initiate</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 70%;">Igniter Comp K-31</td> <td style="text-align: center;">2.0</td> </tr> <tr> <td>Igniter Comp K-29</td> <td style="text-align: center;">2.3</td> </tr> </table>	Igniter Comp K-31	2.0	Igniter Comp K-29	2.3	<p><b>Storage:</b></p> <p>Method    Dry</p> <p>Hazard Class (Quantity-Distance)    Class 9</p> <p>Compatibility Group                              Group 0</p> <p>Exudation    None</p> <p><u>100°C Vacuum Stability Test,</u> <u>cc gas/40 hrs:</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">Initial Value</td> <td style="text-align: right;">0.5</td> </tr> <tr> <td>After 2 hours at 65°C</td> <td style="text-align: right;">0.86</td> </tr> <tr> <td>After 2 hours at 65°C, 75% RH</td> <td style="text-align: right;">1.46</td> </tr> </table> <p><u>Sensitivity to Electrostatic</u> <u>Discharge, Joules:</u> (b)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">Unconfined</td> <td style="text-align: right;">&gt;12.5</td> </tr> <tr> <td>Confined</td> <td style="text-align: right;">0.2</td> </tr> </table> <p><u>Compatibility with Metals:</u></p> <p>Dry - Compatible with all metals when moisture content is less than 0.20%.</p> <p>Wet - Attacks all common metals except stainless steel.</p> <p><u>Heat of:</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 70%;">Explosion, cal/gm</td> <td style="text-align: right;">684</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td style="text-align: right;">271</td> </tr> </table>	Initial Value	0.5	After 2 hours at 65°C	0.86	After 2 hours at 65°C, 75% RH	1.46	Unconfined	>12.5	Confined	0.2	Explosion, cal/gm	684	Gas Volume, cc/gm	271
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Preparation:

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

**WARNING**

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

Origin:

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

Destruction by Chemical Decomposition:

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

References:<sup>7</sup>

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

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

Black Powder

AMCP 706-177

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	91	222	163	354	65	56	347	188	379
710	471	272	363	454	415	176	407	318	819
850	661	322	453	544	545	356	437	428	839
1010	901	472	843	554	605	686	547	558	849
1450	1111	492	1043	574	1145	746	757	598	859
	1241	582	1153	594	1275	1256	847	608	899
	1451	762	1243	654	1815	1316	1097	618	1259
	1541	872	1333	664	1885	1536	1737	698	1309
	1711	1022	1493	774	1905	1576	1797	838	1339
	1911	1622	1583	844	1915	1586	1807	898	1349
	1951	1712	1643	1114		1946	1827	1068	1589
	2051	1802	1813	1154				1388	1739
		1912	1843	1244				1528	1869
			1973	1504				1778	1889
								1808	
								1838	
								1928	
								2178	

<b>Composition:</b> % C 19.9 H 2.9 N 17.5 O 59.7 C/H Ratio 0.13	<p> <math>\text{H}_2\text{C}-\text{ONO}_2</math>  <math>\text{H}_2\text{C}</math>  <math>\text{HC}-\text{ONO}_2</math>  <math>\text{H}_2\text{C}-\text{ONO}_2</math> </p>	Molecular Weight: $(\text{C}_4\text{H}_7\text{N}_3\text{O}_9)$ 241
		Oxygen Balance: CO, % -17 CO % 10
		Density: gm/cc Liquid 1.52
		Melting Point: °C
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 58 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. <1 Sample Wt, mg	Boiling Point: °C	Refractive Index, $n_{20}^D$ 1.4738 $n_{25}^D$ $n_{30}^D$
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.33 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 48.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 230 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.10	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: Trauzl Test, % TNT: Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs 1.5 % Loss, 2nd 48 Hrs 1.2 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:		
Hygroscopicity: % (a) 100°F, 95% RH, 24 hrs 0.14		
Volatility: 60°C, mg/cm <sup>2</sup> /hr 46		



<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth															
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Hole Volume																							
Hole Depth																							
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Yellow oil</p> <p><b>Principal Uses:</b> Explosive plasticizer for nitrocellulose</p>																						
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Heat of:</b> (a)</p> <table> <tr> <td>Combustion, cal/gm</td> <td>2168</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1457</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>840</td> </tr> </table>	Combustion, cal/gm	2168	Explosion, cal/gm	1457	Gas Volume, cc/gm	840	<p><b>Method of Loading:</b></p> <p><b>Loading Density: gm/cc</b> 1.52</p> <p><b>Storage:</b></p> <p>Method</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation</p> <p><b>Solubility in Water, gm/100 gm, at:</b> (a)</p> <table> <tr> <td>20°C</td> <td>0.08</td> </tr> <tr> <td>60°C</td> <td>0.15</td> </tr> </table> <p><b>Solubility of Water in, gm/100 gm:</b> (a)</p> <table> <tr> <td></td> <td>0.04</td> </tr> </table> <p><b>Solubility, gm/100 gm, at 25°C, in:</b></p> <table> <tr> <td>Ether</td> <td>w</td> </tr> <tr> <td>Alcohol</td> <td>∞</td> </tr> <tr> <td>2:1 Ether:Alcohol</td> <td>∞</td> </tr> <tr> <td>Acetone</td> <td>w</td> </tr> </table> <p><b>Viscosity, centipoises:</b> (a)</p> <table> <tr> <td>Temp. 25°C</td> <td>59</td> </tr> </table>	20°C	0.08	60°C	0.15		0.04	Ether	w	Alcohol	∞	2:1 Ether:Alcohol	∞	Acetone	w	Temp. 25°C	59
Combustion, cal/gm	2168																						
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Ether	w																						
Alcohol	∞																						
2:1 Ether:Alcohol	∞																						
Acetone	w																						
Temp. 25°C	59																						

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<sup>o</sup>-5<sup>o</sup>C. When the agitation was completed, stirring was continued for one and one-half hours. The mixture was poured into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of ether. The combined ether extracts were washed with water, then with a 5% sodium bicarbonate solution and finally with water. The neutralized extract was dried with anhydrous calcium chloride and then the ether was evaporated. The yellow oil was dried in a vacuum desiccator over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

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

References:<sup>8</sup>

(a) J. A. Gallagher, F. Macri, J. Bednarik, and F. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Factory Technical Report No. 19, 10 September 1948.

(b) Also see the following Picatinny Arsenal Technical Reports on Butanetriol Trinitrate: 1755 and 1786.

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<sup>8</sup>See footnote 1, page 10.



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b></p> <p>Density, gm/cc                      1.62</p> <p>Charge Wt, lb                            2.102</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT                                    703</p> <p>For Subject HE                            1138</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <p>Density, gm/cc                      1.64</p> <p>Charge Wt, lb                            0.861</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT                                    514</p> <p>For Subject HE                            710</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>
<p><b>Fragment Velocity: ft/sec</b></p> <p>At 9 ft                                      2800</p> <p>At 25½ ft                                    2530</p> <p>Density, gm/cc                      1.61</p>	<p><b>Color:</b>                                    White-buff</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b></p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p><b>Air, Confined:</b></p> <p>Impulse</p> <p><b>Under Water:</b></p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p> <p><b>Underground:</b></p> <p>Peak Pressure</p> <p>Impulse</p> <p>Energy</p>	<p><b>Principal Uses:</b>      HE, SAP, AP projectiles; Shaped Charges</p>
<p><b>Method of Loading:</b>                      Pressed</p>	<p><b>Loading Density: gm/cc</b>                      psi x 10<sup>3</sup></p> <p style="text-align: center;">3    12</p> <p>1.47    1.65</p>
<p><b>Storage:</b></p> <p>Method    Dry</p> <p>Hazard Class (Quantity-Distance)      Class 9</p> <p>Compatibility Group                              Group I</p> <p>Exudation      Does not exude at 65°C when waxes melting sharply at or above 75°C are used.</p>	<p><b>Preparation:</b></p> <p>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.</p> <p>Effect of Temperature on Rate of Detonation:    (e)</p> <p>16 hrs at, °C    -54                      21</p> <p>Density, gm/cc    1.51                      1.51</p> <p>Rate, m/sec    7600                      7620</p> <p><b>Booster Sensitivity Test:</b>    (d)</p> <p>Condition    Pressed</p> <p>Tetryl, gm    100</p> <p>Wax in. for 50% Detonation    1.70</p> <p>Density, gm/cc    1.62</p> <p><b>Heat of:</b></p> <p>Combustion, cal/gm    1210</p>

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:<sup>9</sup>

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

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

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

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

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

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

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

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

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

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

<p><b>Booster Sensitivity Test:</b>                  Condition (d)                  Cast                  Tetryl, gm 100                  Wax, in. for 50% Detonation 1.40                  Wax, gm                  Density, gm/cc 1.69</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (AH, kcal/mol)                  Temperature Range, °C                  Phase</p>																																						
<p><b>Heat of:</b> (e)                  Combustion, cal/gm 2790                  Explosion, cal/gm 1240                  Gas Volume, cc/gm                  Formation, cal/gm                  Fusion, cal/gm (1) 8.0</p>	<p><b>Armor Plate Impact Test:</b> (e)</p> <p><b>60 mm Mortar Projectile:</b>                  50% Inert, Velocity, ft/sec 209                  Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b></p> <table border="1"> <thead> <tr> <th>Plate Thickness, inches</th> <th>Trials</th> <th>% Inert</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>4</td> <td>100</td> </tr> <tr> <td>1¼</td> <td>6</td> <td>50</td> </tr> <tr> <td>1½</td> <td>2</td> <td>0</td> </tr> <tr> <td>1¾</td> <td>0</td> <td></td> </tr> </tbody> </table>	Plate Thickness, inches	Trials	% Inert	1	4	100	1¼	6	50	1½	2	0	1¾	0																								
Plate Thickness, inches	Trials	% Inert																																					
1	4	100																																					
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<p><b>Specific Heat: cal/gm/°C</b> (1)</p> <table border="1"> <thead> <tr> <th>°C</th> <th></th> <th>°C</th> <th></th> </tr> </thead> <tbody> <tr> <td>-75</td> <td>0.235</td> <td>75</td> <td>0.376</td> </tr> <tr> <td>0</td> <td>0.220</td> <td>85</td> <td>0.354</td> </tr> <tr> <td>25</td> <td>0.254</td> <td>90</td> <td>0.341</td> </tr> <tr> <td>50</td> <td>0.305</td> <td>100</td> <td>0.312</td> </tr> </tbody> </table>	°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	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p> <p>Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b></p> <table border="1"> <thead> <tr> <th></th> <th>No Seal</th> <th>Seal</th> </tr> </thead> <tbody> <tr> <td>Height, ft</td> <td>4000</td> <td>4000</td> </tr> <tr> <td>Trials</td> <td>65</td> <td>39</td> </tr> <tr> <td>Unaffected</td> <td>58</td> <td>36</td> </tr> <tr> <td>Low Order</td> <td>2</td> <td>2</td> </tr> <tr> <td>High Order</td> <td>5</td> <td>1</td> </tr> </tbody> </table> <p><b>1000-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p>		No Seal	Seal	Height, ft	4000	4000	Trials	65	39	Unaffected	58	36	Low Order	2	2	High Order	5	1
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<p><b>Burning Rate:</b>                  cm/sec</p>																																							
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C</p>																																							
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                  Volume, %/°C</p>																																							
<p><b>Hardness, Mohs' Scale:</b></p>																																							
<p><b>Young's Modulus:</b>                  E, dynes/cm²                  E, lb/inch²                  Density, gm/cc</p>																																							
<p><b>Compressive Strength: lb/inch² (b)</b> 1610-2580                  Density, gm/cc 1.68</p>																																							
<p><b>Vapor Pressure:</b>                  °C mm Mercury</p>																																							

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



Composition BCompatibility with Metals:

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

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

Preparation:

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

Destruction by Chemical Decomposition:

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

References:<sup>10</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Committee of Divisions 2 and 8, NDRC, Report on 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 111, 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, PAIR No. 2383, November, 1956.

<sup>10</sup>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 Composition B:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1360	1211	1402	1313	1224	1325	1466	1207	1338	1339
1530	1451	1482	1433	1424	1435	1476	1437	1388	1379
2100	2131	1592	1803	1944	1585	1556	1457	1438	1469
2160	2151		1983	2004	1595	1756	1737	1458	1819
2190			2053	2104	1865	1956	1797	1688	2019
			2063		1885	2236	2007	1728	
			2103		2155		2147	1828	
			2233		2125			1838	
					2155			1978	
					2-75			2008	
					2-35			2138	
								2168	

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

Composition B. Desensitized

AMCP 706-177

Composition:	<u>I*</u>	<u>II**</u>	Molecular Weight:	<u>I*</u>	<u>II**</u>
				See Cyclonite	See Comp B
%			Oxygen Balance:		
RDX	60	55.2	CO, %	See Cyclonite	See Comp B
TNT	40	40.0	CO %	See Cyclonite	See Comp B
Wax added. (Standard or Aristowax, 1650/ 1700F)	5		Density: gm/cc	Cast	1.65
Vinylseal (MA28-14), added	2		Melting Point: °C		
Vistanex (BL20)		1.2	Freezing Point: °C		
Albacer Wax		3.6	Boiling Point: °C		
C/H Ratio			Refractive Index, $n_{20}^D$		
			$n_{25}^D$		
			$n_{50}^D$		
Impact Sensitivity, 2 Kg Wt:	<u>I*</u>	<u>II**</u>	Vacuum Stability Test:	<u>I*</u>	<u>II**</u>
Bureau of Mines Apparatus, cm	95		cc/40 Hrs, at		
Sample Wt 20 mg			90°C		
Picatinny Arsenal Apparatus, in.	14	13	100°C	0.99	0.92
Sample Wt, mg	17	16	120°C		
			135°C		
			150°C	11+	11+
Friction Pendulum Test:			200 Gram Bomb Sand Test:	<u>I*</u>	<u>II**</u>
Steel Shoe	Unaffected		Sand, gm	52.7	55.0
Fiber Shoe	Unaffected		Sensitivity to Initiation:	<u>I*</u>	<u>II**</u>
Rifle Bullet Impact Test:	Trials		Minimum Detonating Charge, gm		
	%	<u>I*</u>	Mercury Fulminate		
Explosions		0	Lead Azide	0.22	0.26
Partials		0	Tetryl		
Burned		5	Ballistic Mortar, % TNT:		
Unaffected		95	Trauzl Test, % TNT:		
		100	Plate Dent Test:		
Explosion Temperature:	°C	<u>I*</u>	Method		
Seconds, 0.1 (no cap used)		<u>II**</u>	Condition		
1			Confined		
5 Decomposes	260	270	Density, gm/cc		
10			Brisance, % TNT		
15			Detonation Rate:		
20			Confinement		
75°C International Heat Test:			Condition		
% Loss in 48 Hrs			Charge Diameter, in.		
100°C Heat Test:	<u>I*</u>	<u>II**</u>	Density, gm/cc		
% Loss, 1st 48 Hrs	0.05	0.12	Rate, meters/second		
% Loss, 2nd 48 Hrs	0.19	0.18			
Explosion in 100 Hrs	None	None			
Flammability Index:					
Hygroscopicity: %					
30°C, 90% RH	0.00	0.00			
Volatility:	Ni 1	Ni 1			

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

\*\*Desensitized Comp B, designated 11, uses coated RDX.

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <table border="0"> <tr> <td>Density, gm/cc</td> <td><u>I*</u> 1.65</td> <td><u>II**</u> 1.65</td> </tr> <tr> <td>Charge Wt, lb</td> <td>0.87</td> <td>0.86</td> </tr> </table> <p><b>Total No. of Fragments:</b></p> <table border="0"> <tr> <td>For TNT</td> <td>514</td> <td>514</td> </tr> <tr> <td>For Subject HE</td> <td>609</td> <td>659</td> </tr> </table>	Density, gm/cc	<u>I*</u> 1.65	<u>II**</u> 1.65	Charge Wt, lb	0.87	0.86	For TNT	514	514	For Subject HE	609	659	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
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	Glass Cones	Steel Cones																				
Hole Volume																						
Hole Depth																						
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Yellow-brown</p>																					
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p> <p>*Desensitized Comp B, designated I, uses emulsified wax.                  **Desensitized Comp B, designated 11, uses coated RDX.</p>	<p><b>Principal Uses:</b> Bombs</p>																					
	<p><b>Method of Loading:</b> Cast</p>																					
	<p><b>Loading Density: gm/cc</b> 1.65</p>																					
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation														
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	<p><b>Viscosity, poises:</b></p> <table border="0"> <tr> <td></td> <td><u>I*</u></td> <td><u>II**</u></td> </tr> <tr> <td>Temp, 83°C</td> <td>3.5</td> <td>3.1</td> </tr> <tr> <td>95°C</td> <td>2.6</td> <td>2.7</td> </tr> </table>		<u>I*</u>	<u>II**</u>	Temp, 83°C	3.5	3.1	95°C	2.6	2.7												
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Temp, 83°C	3.5	3.1																				
95°C	2.6	2.7																				
	<p><b>References:</b></p> <p>(a) See the following Picatinny Arsenal Technical Reports on RDX Composition B, Desensitized:</p> <table border="0"> <tr> <td><u>1</u></td> <td><u>3</u></td> <td><u>5</u></td> <td><u>6</u></td> </tr> <tr> <td>2151</td> <td>1313 2053</td> <td>1435 1865</td> <td>1756</td> </tr> </table>	<u>1</u>	<u>3</u>	<u>5</u>	<u>6</u>	2151	1313 2053	1435 1865	1756													
<u>1</u>	<u>3</u>	<u>5</u>	<u>6</u>																			
2151	1313 2053	1435 1865	1756																			

Composition C

AMCP 706-177

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

<p>Fragmentation Test:</p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject <b>HE</b></p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject <b>HE</b></p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <table border="0"> <tr> <td></td> <td>(f)</td> <td>(g)</td> </tr> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td>113</td> <td>114</td> </tr> <tr> <td>Hole Depth</td> <td>101</td> <td>114</td> </tr> </table>		(f)	(g)		Glass Cones	Steel Cones	Hole Volume	113	114	Hole Depth	101	114
		(f)	(g)										
		Glass Cones	Steel Cones										
	Hole Volume	113	114										
	Hole Depth	101	114										
<p>Color: White</p>													
<p>Principal Uses: Plastic demolition explosive</p>													
<p>Method of Loading: Hand tamped</p>													
<p>Loading Density: gm/cc 1.49</p>													
<p>Fragment Velocity: ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Exudes above 40°C</p>												
<p><b>Blast (Relative to TNT):</b></p> <p>Air:                  Peak Pressure                  Impulse                  Energy</p> <p>Air, Confined:                  Impulse</p> <p>Under Water:                  Peak Pressure                  Impulse                  Energy</p> <p>Underground:                  Peak Pressure                  Impulse                  Energy</p>	<p><u>Plasticity:</u></p> <table border="0"> <tr> <td>Below 0°C</td> <td>Brittle (0°C)</td> </tr> <tr> <td>0-40°C</td> <td>Plastic</td> </tr> <tr> <td>Above 40°C</td> <td>Exudes (40°C)</td> </tr> </table> <p><u>References :</u></p> <p>See references for Composition C-4.</p>	Below 0°C	Brittle (0°C)	0-40°C	Plastic	Above 40°C	Exudes (40°C)						
Below 0°C	Brittle (0°C)												
0-40°C	Plastic												
Above 40°C	Exudes (40°C)												

Composition C-2

AMCP 706-177

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> White</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Plastic demolition explosive</p>									
	<p><b>Method of Loading:</b> Hand tamped</p>									
	<p><b>Loading Density:</b> gm/cc 1.57</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: center;">Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: center;">Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td style="text-align: center;">Group I</td> </tr> <tr> <td>Exudation</td> <td style="text-align: center;">Volatilizes above 52°C</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	Volatilizes above 52°C	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation	Volatilizes above 52°C									
	<p><b>Plasticity:</b></p> <table border="0"> <tr> <td>Below 0°C</td> <td style="text-align: center;">Plastic (-30°C)</td> </tr> <tr> <td>0-40°C</td> <td style="text-align: center;">Plastic</td> </tr> <tr> <td>above 40°C</td> <td style="text-align: center;">Hard (52°C)*</td> </tr> </table> <p>*Due to volatilization of plasticizer.</p> <p><b>References:</b></p> <p>See references for Composition C-4.</p>	Below 0°C	Plastic (-30°C)	0-40°C	Plastic	above 40°C	Hard (52°C)*			
Below 0°C	Plastic (-30°C)									
0-40°C	Plastic									
above 40°C	Hard (52°C)*									



Composition: % HDX 77 Tetryl 3 TNT 4 DNT 10 MNT 5 NC 1  C/H Ratio	Molecular Weight:  Oxygen Balance: CO, % CO %  Density: gm/cc  Melting Point: °C  Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 33	Boiling Point: °C  Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 1.21 120°C 11+ 135°C 150°C
Rifle Bullet Impact Test: Trials Explosions 0 Partial 40 Burned 0 Unaffected 60	200 Gram Bomb Sand Test: Sand, gm 53.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.08
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 126 Trauzl Test, % TNT: (b) 117 Plate Dent Test: (c)
100°C Heat Test: % Loss, 1st 48 Hrs 3.20 % Loss, 2nd 48 Hrs 1.63 Explosion in 100 Hrs None	Method B Condition Hand tamped Confined NO Density, gm/cc 1.57 Brisance, % TNT 118
Flammability Index:	Detonation Rate: (d) Confinement None Condition Hand tamped Charge Diameter, in. 1.0 Density, gm/cc 1.60 Rate, meters/second 7625
Hygroscopicity: % 30°C, 95% RH 2.4	
Volatility: 25°C, 5 days 1.15	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b></p> <p>Density, gm/cc 158 Charge <i>Wt</i>, lb 2045</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT 703 For Subject HE 944</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <p>Density, gm/cc 1.60 Charge <i>Wt</i>, lb 0.842</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT 514 For Subject HE 671</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p> <hr/> <p><b>Color:</b> Yellow</p> <hr/> <p><b>Principal Uses:</b> Plastic demolition explosive</p> <hr/> <p><b>Method of Loading:</b> Hand tamped</p> <hr/> <p><b>Loading Density:</b> gm/cc 1.58</p>
<p><b>Fragment Velocity:</b> ft/sec</p> <p>At 9 ft At 25½ ft</p> <p>Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Exudes at 77°C</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b></p> <p>Peak Pressure 105 Impulse 109 Energy</p> <p><b>Air, Confined:</b></p> <p>Impulse</p> <p><b>Under Water:</b></p> <p>Peak Pressure Impulse Energy</p> <p><b>Underground:</b></p> <p>Peak Pressure Impulse Energy</p>	<p><b>Plasticity:</b></p> <p>Below 0°C Hard (-29°C) 0-40°C Plastic Above 40°C Exudes (77°C)</p> <p><b>Booster Sensitivity Test:</b> (h)</p> <p>Condition Pressed Tetryl, gm 100 <i>Wax</i>, in. for 50% Detonation 1.36 Density, gm/cc 1.62</p> <p><b>References:</b></p> <p>See references for Composition C-4.</p>

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p><b>Color:</b> Light brown</p> <hr/> <p><b>Principal Uses:</b> Plastic demolition explosive</p> <hr/> <p><b>Method of Loading:</b> Hand tamped</p> <hr/> <p><b>Loading Density:</b> gm/cc                      1.60</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth								
	Glass Cones	Steel Cones														
Hole Volume																
Hole Depth																
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>None at 77°C</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None at 77°C							
Method	Dry															
Hazard Class (Quantity-Distance)	Class 9															
Compatibility Group	Group I															
Exudation	None at 77°C															
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Effect of Temperature on Rate of Detonation:</b> (i)</p> <table border="0"> <tr> <td>16 hrs at, °C</td> <td>-54</td> <td>21</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.36</td> <td>1.35</td> </tr> <tr> <td>Rate, m/sec</td> <td>7020</td> <td>7040</td> </tr> </table> <p><b>Plasticity:</b></p> <table border="0"> <tr> <td>Below 0°C</td> <td>Plastic (-57°C)</td> </tr> <tr> <td>0-40°C</td> <td>Plastic</td> </tr> <tr> <td>Above 40°C</td> <td>Plastic (77°C)</td> </tr> </table>	16 hrs at, °C	-54	21	Density, gm/cc	1.36	1.35	Rate, m/sec	7020	7040	Below 0°C	Plastic (-57°C)	0-40°C	Plastic	Above 40°C	Plastic (77°C)
16 hrs at, °C	-54	21														
Density, gm/cc	1.36	1.35														
Rate, m/sec	7020	7040														
Below 0°C	Plastic (-57°C)															
0-40°C	Plastic															
Above 40°C	Plastic (77°C)															

Preparation:

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

Composition C-4 is prepared by hand kneading and rolling, or in a Schrader Bowl mixer, RDX of 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:<sup>11</sup>

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.  
L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.  
M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NDRC Contract W-672-ORD-5723.
- (h) L. C. Smith and S. R. Walton, 4 Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

<sup>11</sup>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:

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

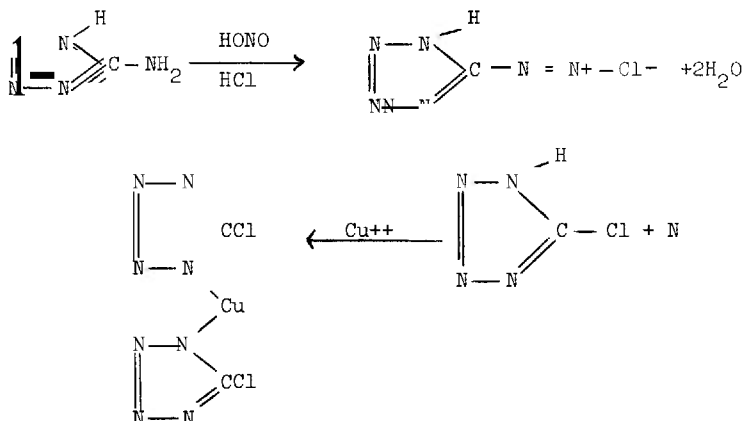
Coyorition:  <table style="display: inline-table; vertical-align: middle;"> <tr> <td style="padding-right: 10px;">C</td> <td style="padding-right: 10px;">8.9</td> <td rowspan="5" style="text-align: center; vertical-align: middle;"> </td> </tr> <tr> <td>N</td> <td>41.5</td> </tr> <tr> <td></td> <td>26.2</td> </tr> <tr> <td></td> <td>23.4</td> </tr> <tr> <td colspan="2">C/H Ratio</td> </tr> </table>	C	8.9		N	41.5		26.2		23.4	C/H Ratio		Molecular Weight: $(CuC_2N_8Cl_2)$ 271
	C	8.9										
	N	41.5										
		26.2										
		23.4										
C/H Ratio												
Oxygen Balance: $CO_2$ % -30 $CO$ % -18												
Density: gm/cc 2.04												
Melting Point: °C												
Freezing Point: °C												
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	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											
Friction Pendulum Test: Steel Shoe Exploded Fiber Shoe Exploded	200 Gram Bomb Sand Test: (f) <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding-right: 10px;">Sand, gm</td> <td style="padding-right: 10px;">27.4</td> <td style="padding-right: 10px;">25.3</td> </tr> <tr> <td>Black powder fuse</td> <td></td> <td>17.0</td> </tr> </table>	Sand, gm	27.4	25.3	Black powder fuse		17.0					
Sand, gm		27.4	25.3									
Black powder fuse			17.0									
Rifle Bullet Impact Test: Trials <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;"></td> <td style="text-align: center;">%</td> </tr> <tr> <td>Explosions</td> <td></td> </tr> <tr> <td>Partials</td> <td></td> </tr> <tr> <td>Burned</td> <td></td> </tr> <tr> <td>Unaffected</td> <td></td> </tr> </table>		%	Explosions		Partials		Burned		Unaffected			
	%											
Explosions												
Partials												
Burned												
Unaffected												
Explosion Temperature: °C Seconds, 0.1 (no cap used) <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%; text-align: center;">1</td> <td style="width: 20%;"></td> </tr> <tr> <td style="text-align: center;">5</td> <td style="text-align: center;">305</td> </tr> <tr> <td style="text-align: center;">10</td> <td></td> </tr> <tr> <td style="text-align: center;">15</td> <td></td> </tr> <tr> <td style="text-align: center;">20</td> <td></td> </tr> </table>	1		5	305	10		15		20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 0.30 Tetryl 0.10	
1												
5	305											
10												
15												
20												
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:											
100°C Heat Test: <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">% Loss, 1st 48 Hrs</td> <td style="text-align: center;">2.67</td> </tr> <tr> <td>% Loss, 2nd 48 Hrs</td> <td style="text-align: center;">0.10</td> </tr> <tr> <td>Explosion in 100 Hrs</td> <td style="text-align: center;">None</td> </tr> </table>	% Loss, 1st 48 Hrs	2.67	% Loss, 2nd 48 Hrs	0.10	Explosion in 100 Hrs	None	Trauzl Test, % TNT:					
% Loss, 1st 48 Hrs	2.67											
% Loss, 2nd 48 Hrs	0.10											
Explosion in 100 Hrs	None											
Flammability Index:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT											
Hygroscopicity: % 30°C, 90%RH 3.11	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second											
Volatility:												

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> Hole Volume Hole Depth																								
	<p><b>Color:</b> Blue</p>																								
	<p><b>Principal Uses:</b> Primary explosive</p>																								
	<p><b>Method of Loading:</b> Pressed</p>																								
	<table border="1"> <tr> <td><b>Loading Density:</b> gm/cc</td> <td colspan="2">psi x 10<sup>3</sup></td> <td>(c)</td> </tr> <tr> <td style="text-align: center;">10      20</td> <td style="text-align: center;">40</td> <td style="text-align: center;">70</td> <td></td> </tr> <tr> <td style="text-align: center;">1.49    1.63</td> <td style="text-align: center;">1.74</td> <td style="text-align: center;">1.86</td> <td></td> </tr> </table>	<b>Loading Density:</b> gm/cc	psi x 10 <sup>3</sup>		(c)	10      20	40	70		1.49    1.63	1.74	1.86													
<b>Loading Density:</b> gm/cc	psi x 10 <sup>3</sup>		(c)																						
10      20	40	70																							
1.49    1.63	1.74	1.86																							
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method: Wet</p> <p>Hazard Class (Quantity-Distance): Class 9</p> <p>Compatibility Group: Group M</p> <p>Exudation: None</p>																								
<p><b>Blost (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Stab Sensitivity:</b> (c)</p> <table border="1"> <tr> <th>Density gm/cc</th> <th colspan="3">Firing Point (inch-ounces)</th> </tr> <tr> <td></td> <th>0%</th> <th>50%</th> <th>100%</th> </tr> <tr> <td>1.49</td> <td>9</td> <td>11</td> <td>15</td> </tr> <tr> <td>1.63</td> <td>8.5</td> <td>10</td> <td>12</td> </tr> <tr> <td>1.74</td> <td>6</td> <td>7</td> <td>9</td> </tr> <tr> <td>1.86</td> <td>4</td> <td>5</td> <td>6</td> </tr> </table> <p><b>Heat of:</b></p> <p>Explosion, cal/gm: 432</p> <p><b>Specific Heat, cal/gm/°C</b></p> <p>Temp range 0°-30°C: 0.155                  Wt of sample, gm: 0.8910</p>	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
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																						



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<sup>o</sup>-15<sup>o</sup>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%.

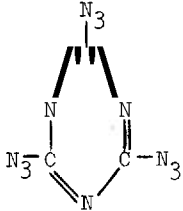
Origin:

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: <sup>12</sup>

- (a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PAIR No. 2136, February 1955.
- (b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances for Application in Ammunition, PAIR 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, PAIR No. 2146, February 1955.

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

Composition: % C 17.6 N 82.4   C/H Ratio	Molecular Weight: (C <sub>3</sub> N <sub>12</sub> )	204
	Oxygen Balance:	
	CO, %	-47.1
	CO %	-23.5
	Density: gm/cc	Crystal
Melting Point: °C		94
Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg wt 7 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. - Sample Wt, mg -	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup>	
	n <sub>25</sub> <sup>D</sup>	
	n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test:	
Rifle Bullet Impact Test: Trials	cc/40 Hrs, at	
Explosions %	90°C	
Partials	100°C	
Burned	120°C	
Unaffected	135°C	
	150°C	
Explosion Temperature: °C	200 Gram Bomb Sand Test:	
Seconds, 0.1 (no cap used) 252	Sand, gm	32.2
1	Sensitivity to Initiation:	
5	Minimum Detonating Charge, gm	
10	Mercury Fulminate	-
15	Lead Azide	0.20
20	Tetryl	0.10
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
100°C Heat Test:	Trauzl Test, % TNT:	
% Loss, 1st 48 Hrs	Plate Dent Test:	
% Loss, 2nd 48 Hrs	Method	
Explosion in 100 Hrs	Condition	
Flammability Index:	Confined	
Hygroscopicity: %	Density, gm/cc	
Volatility: Decomposes above 100°C	Brisance, % TNT	
	Detonation Rate:	
	Confinement	-
	Condition	-
	Charge Diameter, in.	0.3
	Density, gm/cc	1.15
	Rate, meters/second	5550-5600

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Colorless</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Not used because of difficulty in controlling sensitivity.</p>									
	<p><b>Method of Loading:</b> Pressed</p>									
	<p><b>Loading Density: gm/cc</b></p> <table border="0"> <tr> <td>At 200 atmospheres</td> <td style="text-align: center;">1.4</td> </tr> <tr> <td>At 800 atmospheres</td> <td style="text-align: center;">1.5</td> </tr> </table>	At 200 atmospheres	1.4	At 800 atmospheres	1.5					
At 200 atmospheres	1.4									
At 800 atmospheres	1.5									
	<p><b>Storage:</b></p> <p>Method</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group</p> <p>Exudation None</p>									



<b>Composition:</b> 16.3 2.7 N 37.8 O 43.2 C/H Ratio 0.095		<b>Molecular Weight:</b> (C <sub>3</sub> H <sub>6</sub> N <sub>6</sub> O <sub>6</sub> ) 222
		<b>Oxygen Balance:</b> CO <sub>2</sub> % -22 CO % 0.0
		Density: gm/cc Crystal 1.82
		Melting Point: °C 204
		Freezing Point: °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg 8 Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg	<b>Boiling Point:</b> °C	
<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe Unaffected	<b>Refractive Index, n<sub>D</sub><sup>D</sup>:</b> n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
<b>Rifle Bullet Impact Test:</b> Trials Explosions 100 Partial 0 Burned 0 Unaffected 0	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 0.7 120°C 0.9 135°C 150°C 2.5	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 405 1 316 5 Decomposes 260 10 240 15 235 20 -	<b>200 Gram Bomb Sand Test:</b> Sand, gm 60.2	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs 0.03	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.19* Lead Azide 0.05* * Tetryl * Alternative initiating charges	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.04 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	<b>Ballistic Mortar, % TNT: (a)</b> 150 <b>Trauzl Test, % TNT: (b)</b> 157 <b>Plate Dent Test: (c)</b> Method A Condition Pressed Confined Yes Density, gm/cc 1.50 Brisance, % TNT 135	
<b>Flammability Index: (d)</b> 278	<b>Detonation Rate:</b> Confinement None Condition Pressed Charge Diameter, in. 1.0 Density, gm/cc 1.65 Rate, meters/second 8180	
<b>Hygroscopicity: % 25°C, 100% RH</b> 0.02		
<b>Volatility:</b> Ni 1		

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

<p>Booster Sensitivity Test:                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p>Decomposition Equation: <math>(i) 18.5</math>                  Oxygen, atoms/sec <math>10^{18.5}</math>                  (Z/sec)                  Heat, kilocalorie/mole 47.5                  (AH, kcal/mol)                  Temperature Range, °C 213-299                  Phase Liquid</p>																				
<p>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<sub>3</sub>) 7.169*                  *Assuming cyclonite unimolecular</p>	<p>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</p>																				
<p>Specific heat: cal/gm/°C  <table border="1"> <thead> <tr> <th>°C</th> <th></th> <th>°C</th> <th></th> </tr> </thead> <tbody> <tr> <td>20</td> <td>0.298</td> <td>100</td> <td>0.406</td> </tr> <tr> <td>40</td> <td>0.331</td> <td>120</td> <td>0.427</td> </tr> <tr> <td>60</td> <td>0.360</td> <td>140</td> <td>0.446</td> </tr> <tr> <td>80</td> <td>0.384</td> <td></td> <td></td> </tr> </tbody> </table></p>	°C		°C		20	0.298	100	0.406	40	0.331	120	0.427	60	0.360	140	0.446	80	0.384			
°C		°C																			
20	0.298	100	0.406																		
40	0.331	120	0.427																		
60	0.360	140	0.446																		
80	0.384																				
<p>Burning Rate:                  cm/sec</p>																					
<p>Thermal Conductivity: <math>(h) 10^{-4}</math>                  cal/sec/cm/°C 1.263 <math>6.91 \times 10^{-4}</math>                  Density, gm/cc 1.533 <math>6.98 \times 10^{-4}</math></p>																					
<p>Coefficient of Expansion:                  Linear, %/°C                   Volume, %/°C</p>																					
<p>Hardness, Mohs' Scale: 2.5</p>																					
<p>Young's Modulus:                  E, dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>																					
<p>Compressive Strength: lb/inch<sup>2</sup></p>																					
<p>Vapor Pressure:                  °C mm Mercury</p>	<p>Bomb Drop Test:                   T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:                   Mox 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</p>																				



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

<u>Water</u>		<u>Alcohol</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
30	0.005	0	0.040	20	7.3	20	0.05	0	0.015
50	0.025	20	0.105	40	11.5	40	0.09	20	0.02
70	0.076	40	0.240	60	18.	60	0.20	40	0.05
90	0.19	60	0.579			80	0.41	60	0.13
100	0.28	78	1.195					80	0.30
								100	0.65
<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Methanol</u>		<u>Ether</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
28	2.9	50	0.005	0	0.14	10	0.05	80	4.4
94	18.	60	0.007	20	0.23	20	0.056	85	5.0
		70	0.009	40	0.47	30	0.076	90	5.55
				60	1.1			95	6.2
								100	7.0
								105	7.9
<u>Isoamyl alcohol</u>		<u>Methyl acetate</u>		<u><del>β</del>-Ethoxyethyl acetate</u>		<u>Chlorobenzene</u>		<u>Trichloroethylene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.02	20	2.9	20	0.15	20	0.33	20	0.20
20	0.03	30	3.3	30	0.16	30	0.44	30	0.22
40	0.065	40	4.1	40	0.19	40	0.56	40	0.24
60	0.22	50	5.6	50	0.25	50	0.74	50	0.26
80	0.54								
100	1.35								
<u>Tetra-chloroethane</u>		<u>Isopropanol</u>		<u>Isobutanol</u>		<u>Chloroform</u>		<u>Mesityloxide</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
38	0.09	38	0.18	23	0.0	20	0.01	27	3.2
								97	12.2
<u>Cyclohexanone</u>		<u>Nitrobenzene</u>		<u>Nitroethane</u>		<u>Cyclopentanone</u>		<u>Acetonitrile</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
25	12.7	25	1.5	28	3.6	28	11.5	28	11
97	25	97	12.4	93	19	90	37	82	33
<u>Methyl ethyl ketone</u>									
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
28	5.6								
95	14								



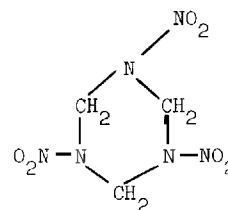
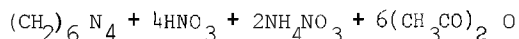
Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

<u>Solvent</u>	<u>Boiling Point, °C</u>	<u>Grade or Source*</u>	<u>Solubility</u>		<u>Crystalline Form</u>
			<u>28°C</u>	<u>Heated</u>	
Acetone	56	CP	8.2	16.5 at 60°C	hexagonal-thick
Cyclohexanone	155.6	CP	13.0	24.0 at 93°C	cubic (massive form)
Nitromethane	100.8		1.5	12.4 at 97°C	plates
Acetonitrile	81.6	Miacet Chem. Co.	11.3	33.4 at 93°C	plates
1-Nitropropane	126.5	EK Pract	1.4	10.6 at 93°C	short needles
2-Nitropropane	120	EK Pract	2.3	11.6 at 93°C	short needles
2,4-Pentanedione	140.5	Carbide & Carbon	2.9	18.3 at 93°C	flat prisms
Methylisobutylketone	115.8		2.4	9.6 at 93°C	long prisms
n-Propylacetate	101.6	EK Red Label	1.5	6.0 at 93°C	long prisms, some cubic
n-Butylformate	105.6	EK Red Label	1.4	4.6 at 93°C	long prisms
Ethyl acetate	77.1	Baker's CP	2.0	6.1 at boil.	hexagonal plates
n-Propylpropionate	121	EK Red Label	0.8	1.6 at 93°C	short prisms, some cubic
Butylacetate	126.5	EK Technical	1.1	4.0 at 93°C	long prisms
Methylethylketone	79.6		5.6	13.9 at boil.	coarse plates
Nitroethane	114.2	EK Red Label	3.6	19.5 at 93°C	plates
Isopropylacetate	88-90	CP	1.1	3.2 at boil.	long prisms
Mesityloxiide	128	EK Red Label	4.8	14.5 at 93°C	plates
n-Amylacetate	146	CP	1.0	2.1 at 93°C	prisms
Dimethylcarbonate	88-91	EK Red Label	1.4	6.6 at boil.	plates
Diethylcarbonate	125-126.5	EK Red Label	0.7	3.2 at 93°C	prisms
Isoamylacetate	132	CP	1.2	3.6 at 93°C	prisms
Ethylpropionate	98-100	EK Red Label	3.0	10.7 at 93°C	fairly thick hex plates
Methyl-n-butyrate	101.5-103.5	EK Red Label	1.2	4.9 at 93°C	needles
Cyclopentanone	130.6	EK Red Label	11.5	39.0 at 93.5°C	hexagonal plates
Acrylonitrile	77.3	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.

Preparation:

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



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

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

Origin:

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

Destruction by Chemical Decomposition:

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

References:<sup>14</sup>

- (a) 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.

<sup>14</sup>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. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.

(j) International Critical Tables.

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

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

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

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

<p><b>Booster Sensitivity Test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (AH, kcal/mole)                  Temperature Range, °C                  Phase</p>																				
<p><b>Heat of:</b>                  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.</p>	<p><b>Armor Plate Impact Test:</b>                   60 mm Mortar Projectile:                  50% Inert, Velocity, ft/sec                  Aluminum Fineness   <b>500-lb General Purpose Bombs:</b>                   Plate Thickness, inches                   1                  1¼                  1½                  1¾</p>																				
<p><b>Specific Heat: cal/gm/°C (h)</b>  <table border="1"> <thead> <tr> <th colspan="2">°C</th> <th colspan="2">°C</th> </tr> </thead> <tbody> <tr> <td>-75</td> <td>0.220</td> <td>75</td> <td>0.352</td> </tr> <tr> <td>0</td> <td>0.225</td> <td>85</td> <td>0.325</td> </tr> <tr> <td>25</td> <td>0.254</td> <td>90</td> <td>0.332</td> </tr> <tr> <td>50</td> <td>0.296</td> <td>100</td> <td>0.351</td> </tr> </tbody> </table></p>	°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	<p><b>Bomb Drop Test:</b>   <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>                   Max Safe Drop, ft   <b>500-lb General Purpose Bomb vs Concrete:</b>                   Height, ft                  Trials                  Unaffected                  Low Order                  High Order   <b>1000-lb General Purpose Bomb vs Concrete:</b>                   Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p>
°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																		
<p><b>Burning Rate:</b>                  cm/sec</p>																					
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C</p>																					
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                   Volume, %/°C</p>																					
<p><b>Hardness, Mohs' Scale:</b></p>																					
<p><b>Young's Modulus:</b>                  E, dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>																					
<p><b>Compressive Strength: lb/inch<sup>2</sup></b></p>																					
<p>°C                      mm Mercury</p>																					

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.72                  Charge Wt, lb 2.22</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 1514</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth					
	Glass Cones	Steel Cones									
	Hole Volume										
	Hole Depth										
	<p><b>Color:</b> Yellow-buff</p>										
<p><b>Principal Uses:</b> Shaped charge bomb especially fragmentation; HE projectiles; grenades</p>											
<p><b>Method of Loading:</b> Cast</p>											
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b> 1.71</p>										
<p><b>Blast (Relative to TNT):</b> (d)</p> <p><b>Air:</b>                  Peak Pressure 111                  Impulse 126                  Energy --</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation			
Method	Dry										
Hazard Class (Quantity-Distance)	Class 9										
Compatibility Group	Group I										
Exudation											
	<p><b>Preparation:</b> See Composition B</p> <p><b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.</p> <p><b>Black Modulus at Room Temperature (25°-30°C):</b></p> <table> <tr> <td>Dynes/cm<sup>2</sup> x 10<sup>-10</sup></td> <td>3.09</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.74</td> </tr> </table> <p><b>Absolute Viscosity, poises: *</b></p> <table> <tr> <td>Temp, 85°C</td> <td>210**</td> </tr> <tr> <td>90°C</td> <td>--</td> </tr> </table> <p><b>Efflux Viscosity, Saybolt Seconds:</b></p> <table> <tr> <td>Temp, 85°C</td> <td>9-14</td> </tr> </table> <p>* Compositions using Spec Grade Type A, Class A RDX.                  ** Composition prepared using RDX of optimum particle size.</p>	Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>	3.09	Density, gm/cc	1.74	Temp, 85°C	210**	90°C	--	Temp, 85°C	9-14
Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>	3.09										
Density, gm/cc	1.74										
Temp, 85°C	210**										
90°C	--										
Temp, 85°C	9-14										

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>            Density, gm/cc 1.71            Charge Wt, lb 2.213</p> <p><b>Total No. of Fragments:</b>            For TNT 703            For Subject HE 1165</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>            Density, gm/cc 1.72            Charge Wt, lb 0.923</p> <p><b>Total No. of Fragments:</b>            For TNT 514            For Subject HE 828</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> <th>(e)</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td>130</td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> Yellow-buff</p> <p><b>Principal Uses:</b> Shaped charge bombs: especially fragmentation HE projectiles, grenades</p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density:</b> gm/cc 1.71</p>		Glass Cones	Steel Cones	(e)	Hole Volume				Hole Depth		130			
	Glass Cones	Steel Cones	(e)												
Hole Volume															
Hole Depth		130													
<p><b>Fragment Velocity:</b> ft/sec            At 9 ft            At 25½ ft            Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p>														
<p><b>Blast (Relative to TNT):</b> (d)</p> <p><b>Air:</b>            Peak Pressure 110            Impulse 120            Energy --</p> <p><b>Air, Confined:</b>            Impulse</p> <p><b>Under Water:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Underground:</b>            Peak Pressure            Impulse            Energy</p>	<p><b>Preparation:</b> See Composition B</p> <p><b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.</p> <p><b>Absolute Viscosity, poises:*</b></p> <table border="1"> <tbody> <tr> <td>Temp, 85°C</td> <td>--</td> </tr> <tr> <td>90°C</td> <td>53.2</td> </tr> </tbody> </table> <p><b>Efflux Viscosity, Saybolt Seconds:</b></p> <table border="1"> <tbody> <tr> <td>Temp, 85°C</td> <td>5</td> </tr> <tr> <td></td> <td>**</td> </tr> </tbody> </table> <p><b>Heat of:</b></p> <table border="1"> <tbody> <tr> <td>Combustion, cal/gm</td> <td>2685</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1213</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>854</td> </tr> </tbody> </table> <p>* Composition using Spec Grade Type A, Class A RDX.            ** Calculated from composition of mixture.</p>	Temp, 85°C	--	90°C	53.2	Temp, 85°C	5		**	Combustion, cal/gm	2685	Explosion, cal/gm	1213	Gas Volume, cc/gm	854
Temp, 85°C	--														
90°C	53.2														
Temp, 85°C	5														
	**														
Combustion, cal/gm	2685														
Explosion, cal/gm	1213														
Gas Volume, cc/gm	854														



Composition: % RDX                    55  TNT                    35  C/H Ratio	Molecular Weight:                    224
	Oxygen Balance: CO, %                    -40 CO %                    - 9
	Density: gm/cc                    Cast                    1.71
	Melting Point: °C
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C
Friction Pendulum Test: Steel Shoe                    Unaffected Fiber Shoe                    Unaffected	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
Rifle Bullet Impact Test:    Trials  Explosions                    % Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm                    55.4
Explosion Temperature:                    °C Seconds, 0.1 (no cap used) 1 5 Decomposes                    270 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
	Ballistic Mortar, % TNT: (a)                    134
	Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement                    None Condition                    Cast Charge Diameter, in.                    1.0 Density, gm/cc                    1.72 Rate, meters/second                    7975
Flammability Index:	
Hygroscopicity: %                    Ni 1	
Volatility:                    Ni 1	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                      1.71                  Charge Wt, lb                         2.253</p> <p><b>Total No. of Fragments:</b>                  For TNT                                 703                  For Subject HE                         1153</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                      1.71                  Charge Wt, lb                         0.922</p> <p><b>Total No. of Fragments:</b>                  For TNT                                 514                  For Subject HE                         769</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> <td>(c)</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td>130</td> <td></td> </tr> </table>		Glass Cones	Steel Cones	(c)	Hole Volume				Hole Depth		130													
	Glass Cones	Steel Cones	(c)																						
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Hole Depth		130																							
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b>                                 Yellow-buff</p> <p><b>Principal Uses:</b> Shaped charge bombs; especially fragmentation HE projectiles, grenades</p>																								
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Heat of:</b>                                 *</p> <table border="1"> <tr> <td>Combustion, cal/gm</td> <td>2755</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1205</td> </tr> <tr> <td>* Gas Volume, cc/gm</td> <td>845</td> </tr> </table> <p>* Calculated from composition of mixture.</p>	Combustion, cal/gm	2755	Explosion, cal/gm	1205	* Gas Volume, cc/gm	845	<p><b>Method of Loading:</b>                                 Cast</p> <p><b>Loading Density: gm/cc</b>                                 1.71</p> <p><b>Storage:</b></p> <table border="1"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table> <p><b>Preparation:</b> See Composition B</p> <p><b>Origin:</b> Developed by the British between World Wars I and II and standardized in the United States early in World War II.</p> <p><b>Eutectic Temperature, °C:</b>                                 79</p> <table border="1"> <tr> <td>gn RDX/100 gm TNT</td> <td></td> </tr> <tr> <td>79°C</td> <td>4.16</td> </tr> <tr> <td>95°C</td> <td>5.85</td> </tr> </table> <p><b>Absolute Viscosity, poises:*</b></p> <table border="1"> <tr> <td>Temp, 85°C</td> <td>30.2</td> </tr> <tr> <td>90°C</td> <td>26.0</td> </tr> </table> <p>* Composition using Spec Grade Type A, Class A RDX.</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation		gn RDX/100 gm TNT		79°C	4.16	95°C	5.85	Temp, 85°C	30.2	90°C	26.0
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Composition: % RDX 60 TNT 40  C/H Ratio	Molecular Weight: 224	
	Oxygen Balance: CO, % -43 CO % 10	
	Density: gm/cc Cast 1.68	
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 19	Boiling Point: °C	
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$	
Friction Pendulum test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability test: cc/40 Hrs, at 90°C 100°C 120°C 0.29 135°C 150°C	
	Rifle Bullet Impact test: Trials Explosions % 5 Partials 55 Burned 25 Unaffected 15	200 Gram Bomb Sand Test: Sand, gm 54.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 280 10 15 20	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	
	Frauzell test, % TNT:	
75°C International Heat test: % Loss in 48 Hrs	Plate Dent test: (b) Method B Condition Cast Confined Nb Density, gm/cc 1.72 Brisance, % TNT 132	
100°C Heat test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.72 Rate, meters/second 7900	
Flammability Index:		
Hygroscopicity: % Ni 1		
Volatility: Ni 1		



References: <sup>15</sup>

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

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

(c) 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-INT, and TNT-Metal Systems, National Northern Summary Report, NN-P-34, April 1956.

(e) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Section 111, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

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

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

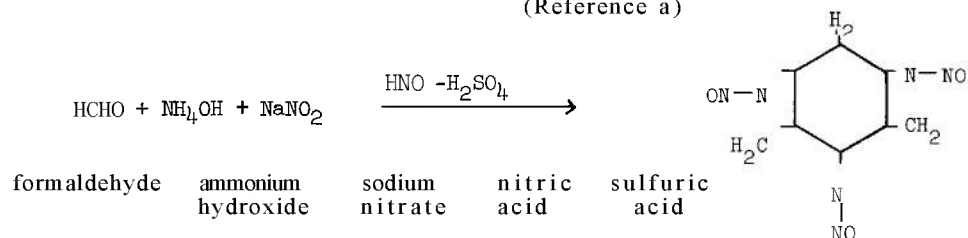
<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1290	1651	1482	1483	1824	1435	1476	1427	1398	1469
1530	1741		1793	1834	1585	1756	1507	1488	1509
			1983	1944		1796	1747	1838	1709
				2004		1876			

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

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

<p>Composition:</p> <table border="0"> <tr> <td>%</td> <td></td> </tr> <tr> <td>C</td> <td>20.6</td> </tr> <tr> <td>H</td> <td>3.5</td> </tr> <tr> <td>N</td> <td>48.3</td> </tr> <tr> <td>O</td> <td>27.6</td> </tr> <tr> <td colspan="2">C/H Ratio 0.12</td> </tr> </table>	%		C	20.6	H	3.5	N	48.3	O	27.6	C/H Ratio 0.12			<table border="0"> <tr> <td>Molecular Weight: (C<sub>3</sub>H<sub>6</sub>N<sub>6</sub>O<sub>3</sub>)</td> <td>174</td> </tr> <tr> <td>Oxygen Balance:</td> <td></td> </tr> <tr> <td>CO, %</td> <td>-55</td> </tr> <tr> <td>CO<sub>2</sub>, %</td> <td>-28</td> </tr> <tr> <td>Density: gm/cc</td> <td></td> </tr> <tr> <td>Melting Point: °C</td> <td>105 to 107</td> </tr> <tr> <td>Freezing Point: °C</td> <td></td> </tr> </table>	Molecular Weight: (C <sub>3</sub> H <sub>6</sub> N <sub>6</sub> O <sub>3</sub> )	174	Oxygen Balance:		CO, %	-55	CO <sub>2</sub> , %	-28	Density: gm/cc		Melting Point: °C	105 to 107	Freezing Point: °C	
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<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td align="center">Glass Cones</td> <td align="center">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> </tr> </table>	Glass Cones	Steel Cones	Hole Volume		Hole Depth																			
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<p><b>Method of Loading:</b> Pressed or cast with added melting point depressants</p>																									
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc                      See below</p>																								
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M	Exudation	None																
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	<p><b>Density at Various Pressures:</b> (b)</p> <table border="0"> <thead> <tr> <th></th> <th align="center"><u>lb/inch<sup>2</sup></u></th> <th align="center"><u>gm/cc</u></th> </tr> </thead> <tbody> <tr> <td></td> <td align="center">2,420</td> <td align="center">1.10</td> </tr> <tr> <td></td> <td align="center">4,830</td> <td align="center">1.23</td> </tr> <tr> <td></td> <td align="center">9,650</td> <td align="center">1.37</td> </tr> <tr> <td></td> <td align="center">14,500</td> <td align="center">1.44</td> </tr> <tr> <td></td> <td align="center">24,200</td> <td align="center">1.53</td> </tr> <tr> <td></td> <td align="center">33,800</td> <td align="center">1.57</td> </tr> <tr> <td></td> <td align="center">42,500</td> <td align="center">1.59</td> </tr> </tbody> </table>		<u>lb/inch<sup>2</sup></u>	<u>gm/cc</u>		2,420	1.10		4,830	1.23		9,650	1.37		14,500	1.44		24,200	1.53		33,800	1.57		42,500	1.59
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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.

Orinin:

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

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

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

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

42% Cyclotrimethylene Trinitrosamine  
58% TNT 7,000

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

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:<sup>16</sup>

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

(b) Louis Médard and Maurice Dutour, "Étude Des Propriétés De La Cyclotriméthylène Trinitrosamine," Mém poudr, 37, 1924 (1954).

(c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.

(d) Also see the following Picatinny Arsenal Technical Reports on Cyclotrimethylene Trinitrosamine: 1174, 2179.

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

Composition: %		Molecular Weight:	83
Ammonium Nitrate	21	Oxygen Balance:	
RDX	21	CO, %	-46
TNT	40	CO %	-26
Aluminum	18	Density: gm/cc	Cast 1.68
C/H Ratio		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	35	Refractive Index, $n_{20}^D$	
Sample Wt 20 mg		$n_{25}^D$	
Picatinny Arsenal Apparatus, in.	13	$n_{30}^D$	
Sample Wt, mg	14		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
		100°C	
Rifle Bullet Impact Test: Trials		120°C	6.15
	%	135°C	
Explosions		150°C	
Partials			
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	58.5
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Ignites	400	Lead Azide	0.20
10		Tetryl	0.10
15			
20		Ballistic Mortar, % TNT: (a)	146
		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test: (b)	
% Loss in 48 Hrs		Method	B
		Condition	Cast
100°C Heat Test:		Confined	Nb
% Loss, 1st 48 Hrs		Density, gm/cc	1.76
% Loss, 2nd 48 Hrs		Brisance, % TNT	102
Explosion in 100 Hrs			
		Detonation Rate: (c)	
Flammability Index:		Confinement	None
		Condition	Cast
Hygroscopicity: %		Charge Diameter, in.	1.6
		Density, gm/cc	1.65
Volatility:		Rate, meters/second	6600

Booster Sensitivity Test: (e) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.35 Wax, gm Density, gm/cc 1.76	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (AH, kcal/mol) Temperature Range, °C Phase
Heat of: (d) Combustion, cal/gm Explosion, cal/gm 1700 Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm	Armor Plate Impact Test:  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness  500-lb General Purpose Bombs:  Plate Thickness, inches  1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (d) -5°C, density 1.75 gm/cc 0.25	
Burning Rate: cm/sec	
Thermal Conductivity: cal/sec/cm/°C 13.2 x 10 <sup>-4</sup> Density 1.75 gm/cc	
Coefficient of Expansion: Linear, %/°C -73°C-75°C 4.5 x 10 <sup>-5</sup>  Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: (d) E, dynes/cm <sup>2</sup> 10.4 x 10 <sup>10</sup> E, lb/inch <sup>2</sup> 1.51 x 10 <sup>6</sup> Density, gm/cc 1.72	
Compressive Strength: lb/inch <sup>2</sup> (d) 3210-3380 Density 1.78 gm/cc	
Vapor Pressure: °C                      mm Mercury	Bomb Drop Test:  T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:  Max Safe Drop, ft  500-lb General Purpose Bomb vs Concrete:  Height, ft Trials Unaffected Low Order High Order  1000-lb General Purpose Bomb vs Concrete:  Height, ft Trials Unaffected Low Order High Order

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume                  Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Gray</p>
<p><b>Blast (Relative to TNT):</b> (d)</p> <p><b>Air:</b>                  Peak Pressure                    118                  Impulse                                127                  Energy                                  138</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                    --                  Impulse                                --                  Energy                                  136</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Depth charge</p>
	<p><b>Method of Loading:</b> Cast</p>
	<p><b>Loading Density:</b> gm/cc                    1.61-1.69</p>
	<p><b>Storage:</b></p> <p>Method    Dry</p> <p>Hazard Class (Quantity-Distance)        Class 9</p> <p>Compatibility Group                            Group I</p> <p>Exudation</p>
	<p><b>Preparation:</b></p> <p>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.</p>

Origin:

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

References:<sup>17</sup>

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

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

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

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

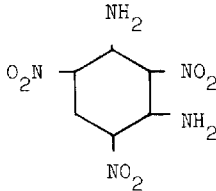
(d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

(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.

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

<b>Composition:</b> % <b>C</b> 29.6 <b>H</b> 2.1 <b>N</b> 28.8 <b>O</b> 39.5  C/H Ratio 0.380		Molecular Weight: (C <sub>6</sub> H <sub>5</sub> N <sub>5</sub> O <sub>6</sub> )	3
		Oxygen Balance: CO, % CO %	
		Density: gm/cc	Crystal 1.83
		Melting Point: °C	(a) 290
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 9	Boiling Point: °C		
	Refractive Index, n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>		
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 46.6		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10		
	Ballistic Mortar, % TNT: 100		
75°C International Heat Test: % Loss in 48 Hrs	Trauzl Test, % TNT:		
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.4 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
	Flammability Index:	Detonation Rate: Confinement None Condition Pressed	
Hygroscopicity: %	Charge Diameter, in. 0.5		
Volatility:	Density, gm/cc 1.65 Rate, meters/second 7500		





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<sub>3</sub> and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13, 60).

Körner and Contardi prepared DATNB by the reaction of either 2,4-dichloro-1,3,5-trinitrobenzene or 2,4-dibromo-1,3,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-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 urcido) 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).

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

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

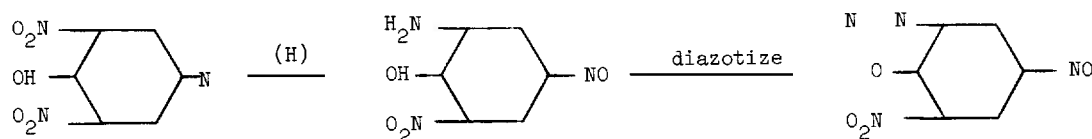
<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Yellow needles</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Percussion caps</p>									
	<p><b>Method of Loading:</b> Pressed</p>									
	<p><b>Loading Density:</b> gm/cc    Apparent    0.27                  At 3000 psi                      1.14</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Under water</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Under water	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
Method	Under water									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group										
Exudation	None									
	<p><b>Solubility:</b></p> <p>Soluble in nitroglycerin, nitrobenzene, aniline, pyridine, concentrated hydrochloric acid, and in most common organic solvents.</p> <p><b>Heat of:</b></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>3243</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>820</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>865</td> </tr> </table> <p><b>Sensitivity to Electrostatic Discharge, Joules:</b> (b) 0.012</p>	Combustion, cal/gm	3243	Explosion, cal/gm	820	Gas Volume, cc/gm	865			
Combustion, cal/gm	3243									
Explosion, cal/gm	820									
Gas Volume, cc/gm	865									

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

Solubility at 50°C

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

Preparation: (Chemistry of Powder and Explosives, Davis)



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

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1860) and studied extensively by L. V. Clark (Ind Eng Chem 25, 663 (1933)). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

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

References: <sup>18</sup>

(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

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

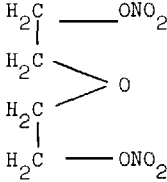
Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(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:

<u>1</u>	<u>2</u>	<u>4</u>	<u>5</u>	<u>7</u>	<u>8</u>	<u>9</u>
150	1352	34	355	827	318	2179
610		214			1838	
2120						

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

<p>Booster Sensitivity test:                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p>Decomposition Equation:                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (AH, kcal/mol)                  Temperature Range, °C                  Phase</p>
<p>Heat of:                  Combustion, cal/gm                      2792                  Explosion, cal/gm                         841                      Gas Volume, cc/gm                     796                  Formation, cal/gm                        2020                  Fusion, cal/gm</p>	<p>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</p>
<p>Specific Heat: cal/gm/°C</p>	
<p>Burning Rate:                  cm/sec</p>	
<p>Thermal Conductivity:                  cal/sec/cm/°C</p>	
<p>Coefficient of Expansion:                  Linear, %/°C                   Volume, %/°C</p>	<p>Bomb Drop Test:</p>
<p>Hardness, Mohs' Scale:</p>	<p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p>
<p>Young's Modulus:                  E, dynes/cm²                  E, lb/inch²                  Density, gm/cc</p>	<p>    Max Safe Drop, ft</p>
<p>Compressive Strength: lb/inch²</p>	<p><b>500-lb General Purpose Bomb vs Concrete:</b></p>
<p>Vapor Pressure:                      °C                      mm Mercury                      20                      0.0036                      60                      0.130</p>	<p>    Height, ft</p>
	<p>    Trials</p>
	<p>    Unaffected</p>
	<p>    Low Order</p>
	<p>    High Order</p>
	<p><b>1000-lb General Purpose Bomb vs Concrete:</b></p>
	<p>    Height, ft</p>
	<p>    Trials</p>
	<p>    Unaffected</p>
	<p>    Low Order</p>
	<p>    High Order</p>





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**.

Structure by Chemical Decomposition:

It is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide solution. Heat is liberated by this reaction but this is not hazardous. The solution is maintained at the reaction of DEGN and continued until solution is complete.

References: <sup>19</sup>

See the following Picatinny Arsenal Technical Reports on DEN:

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

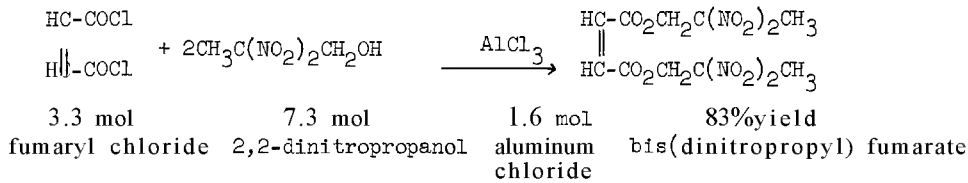
<sup>19</sup>See footnote 1, page 10.

Composition: % <b>C</b> 31.6 <b>H</b> 3.2 <b>N</b> 14.7 <b>O</b> 50.5 C/H Ratio  $\begin{array}{c} \text{CHCO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \\ \parallel \\ \text{CHCO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \end{array}$	Molecular Weight: (C <sub>10</sub> H <sub>12</sub> N <sub>4</sub> O <sub>12</sub> )		380
	Oxygen Balance:		
	CO, %		-59
	CO %		-17
	Density: gm/cc	Crystal	
Melting Point: °C	Form I		89
	Form II		86
Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in, Sample Wt, mg	100+		
	18		
	18		
Friction Pendulum test: Steel Shoe Fiber Shoe	Unaffected		
	Unaffected		
Rifle Bullet Impact test:      Trials  Explosions                              % Partials Burned Unaffected			
Explosion Temperature:              °C Seconds, 0.1 (no cap used)      --- 1    --- 4      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:			
Vacuum Stability test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C			---- 0.66 ---- 0.91
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			1.49 6050

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

Preparation:

(a, b)



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

References:<sup>20</sup>

- (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.

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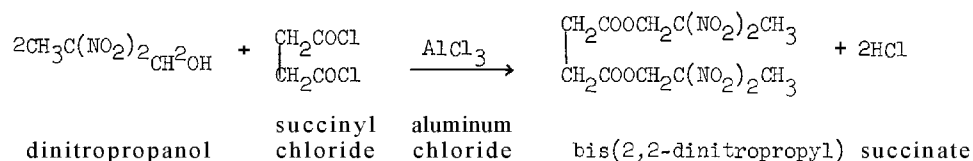
<sup>20</sup>See footnote 1, page 10.

Composition: % C 31.4 H 3.7 N 14.7 O 50.2 C/H Ratio 0.250 $\begin{array}{c} \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \\   \\ \text{CH}_2\text{CO}_2\text{CH}_2\text{C}(\text{NO}_2)_2\text{CH}_3 \end{array}$	Molecular Weight: $(\text{C}_{10}\text{H}_{14}\text{N}_4\text{O}_{12})$ 382
	Oxygen Balance: CO, % -63 CO % -21
	Density: gm/cc Crystal 1.51
	Melting Point: °C 86
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.10 120°C 135°C 150°C
	200 Gram Bomb Sand Test: Sand, gm
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
	Ballistic Mortar, % TNT:
	Traul Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Flammability Index:	
Hygroscopicity: %	
Volatility:	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
		Glass Cones	Steel Cones							
	Hole Volume									
	Hole Depth									
	<p><b>Color:</b></p> <p>White</p>									
<p><b>Principal Uses:</b></p>										
<p><b>Method of Loading:</b></p> <p>Cast</p>										
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b></p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td></td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation	None	
	Method	Dry								
	Hazard Class (Quantity-Distance)									
Compatibility Group										
Exudation	None									
	<p><u>Origin:</u></p> <p>Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.</p>									

Preparation:

(a)



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

References: <sup>21</sup>

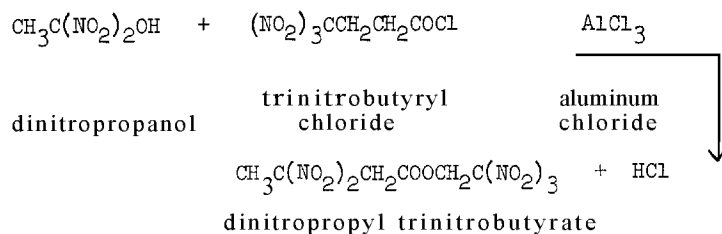
- (a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

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





<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> White</p> <p><b>Principal Uses:</b></p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density:</b> gm/cc 1.67</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																			
	Glass Cones	Steel Cones																									
Hole Volume																											
Hole Depth																											
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>																										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Heat of:</b> (c)</p> <table border="0"> <tr> <td></td> <td></td> <td colspan="2"><u>Solvent</u></td> </tr> <tr> <td>Transition, cal/gm</td> <td></td> <td><u>CCl<sub>4</sub></u></td> <td><u>DMF</u></td> </tr> <tr> <td>I → III</td> <td></td> <td>6.2</td> <td>4.8</td> </tr> <tr> <td>II → I</td> <td></td> <td>-16.6</td> <td>-22.0</td> </tr> </table> <p><b>Heat of Solution, 30°C:</b></p> <table border="0"> <tr> <td></td> <td><u>ΔH Solution, cal/gm</u></td> </tr> <tr> <td><u>Material</u></td> <td></td> </tr> <tr> <td>Form III</td> <td>29.5 8.1</td> </tr> <tr> <td>Form I</td> <td>35.6 12.8</td> </tr> <tr> <td>Form II</td> <td>19.1 -9.1</td> </tr> </table> <p><b>Origin:</b></p> <p>Synthesized in 1952 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland.</p>			<u>Solvent</u>		Transition, cal/gm		<u>CCl<sub>4</sub></u>	<u>DMF</u>	I → III		6.2	4.8	II → I		-16.6	-22.0		<u>ΔH Solution, cal/gm</u>	<u>Material</u>		Form III	29.5 8.1	Form I	35.6 12.8	Form II	19.1 -9.1
		<u>Solvent</u>																									
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Form II	19.1 -9.1																										

Preparation: (a, b)

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

Crystallographic Data: (c)

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

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.

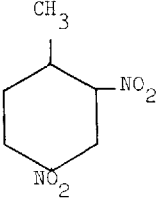
References:<sup>22</sup>

(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.

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

Composition: % C 46.3 H 3.3 N 15.4 O 35.0 C/H Ratio 0.579		Molecular Weight: (C <sub>7</sub> H <sub>6</sub> N <sub>2</sub> O <sub>4</sub> )	1.82
		Oxygen Balance: CO, % CO %	-11.4 - 53
		Density: gm/cc	1.521
		Melting Point: °C	71
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in Sample Wt, mg		Boiling Point: °C	Decomposes 300
		Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Unaffected Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	0.04
Rifle Bullet Impact Test:	Trials	200 Gram Bomb Sand Test: Sand, gm	19.3
	% Explosions 0 Portals 0 Burned 0 Unaffected 100		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	Decomposes 310	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	0.20 0.25
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT: (a)	71
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Trauzl Test, % TNT: (b)	64
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: % 25°C, 100% RH	0.00	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Volatility:			

<p><b>fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p><b>Color:</b> Yellow</p> <hr/> <p><b>Principal Uses:</b> Ingredient of propellant powder, dynamites and plastic explosives</p> <hr/> <p><b>Method of Loading:</b> Pressed, extruded or cast composition</p> <hr/> <p><b>Loading Density:</b> gm/cc                      Variable</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth				
	Glass Cones	Steel Cones										
Hole Volume												
Hole Depth												
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 12</td> </tr> <tr> <td>Compatibility Group</td> <td>Group D</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 12	Compatibility Group	Group D	Exudation				
Method	Dry											
Hazard Class (Quantity-Distance)	Class 12											
Compatibility Group	Group D											
Exudation												
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><u>65.5°C KI Test:</u></p> <table border="0"> <tr> <td>Minutes</td> <td>60+</td> </tr> </table> <p><u>Heat of:</u></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>(b)</td> <td>1545</td> </tr> </table> <p><u>Thermal Conductivity:</u></p> <table border="0"> <tr> <td>cal/sec/cm/°C</td> <td></td> <td></td> </tr> <tr> <td>Density 1.322 gm/cc</td> <td></td> <td>6.28 x 10<sup>-4</sup></td> </tr> </table>	Minutes	60+	Combustion, cal/gm	(b)	1545	cal/sec/cm/°C			Density 1.322 gm/cc		6.28 x 10 <sup>-4</sup>
Minutes	60+											
Combustion, cal/gm	(b)	1545										
cal/sec/cm/°C												
Density 1.322 gm/cc		6.28 x 10 <sup>-4</sup>										

Preparation:

See TNT.

Solubility: gm/100 gm of the following substances.:

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

Solubility at 15°C, in:

<u>Solvent</u>	<u>%</u>	<u>Solvent</u>	<u>%</u>
CHCl <sub>3</sub>	65.076	C <sub>2</sub> H <sub>5</sub> OH (absolute)	3.039
CCl <sub>4</sub>	2.431	Ether (absolute)	9.422
C <sub>6</sub> H <sub>6</sub>	60.644	Acetone	81.901
Toluol	45.470	Ethyl acetate	57.929
C <sub>2</sub> H <sub>5</sub> OH	5.014	CS <sub>2</sub>	2.306
C <sub>2</sub> H <sub>5</sub> OH (96%)	1.916	Pyridine	76.810

Origin:

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

References: <sup>23</sup>

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

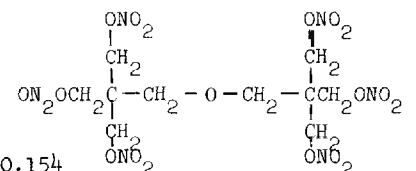
(b) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.

(c) Report AC-2861.

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
810	1351	72	43	394	1615	186	97	768	69
1830	1501	372	233	804	2125	1556	817	938	149
	1651	922	343	1044		1816	837	1538	249
	1781	1142	673	1084		1896			279
	1821	1672	1023	1094					779
	2031	1692	1663	1164					1749
	2221		1743	1324					
			2013	1464					
				1524					
				1674					
				1754					
				2094					

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

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

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



References: <sup>24</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests: Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) A. Stettbacher, Die Schiess und Sprengstoffe, Leipzig, p. 363.
- (c) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-283.
- (d) S. Livingston, Characteristics of Explosives HMX and DPMN, PAIR No. 1561, 6 September 1945.

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

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	Molecular Weight:
	Oxygen Balance: CO, % CO %
	Density: gm/cc      Loading      0.9
	Melting Point: °C
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 22 Sample Wt, mg 19	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
Friction Pendulum Test: Steel Shoe      Unaffected Fiber Shoe      Unaffected	200 Gram Bomb Sand Test: Sand, gm      40.5
Rifle Bullet Impact Test:      Trials Explosions      % Portals Burned Unaffected	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide      0.20 Tetryl      0.15
Explosion Temperature:      °C Seconds, 0.1 (no cap used) 1 5      Ignites      480 10 15 20	Ballistic Mortar, % TNT:      92
75°C International Heat Test: % Loss in 48 Hrs	Treuzl Test, % TNT:
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate bent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:	Detonation Rate: Confinement      None Condition      Hand tamped
Hygroscopicity: % 71°C, 95%RH, 30 days      0.31 Satisfactory	Charge Diameter, in.      1.25 Density, gm/cc      0.9 Rate, meters/second 4397; or 14400 ft/sec
Volatility:	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WÇ-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>
	<p><b>Color:</b> Pink</p>
	<p><b>Principal Uses:</b> Excavation, demolition, and cratering</p>
	<p><b>Method of Loading:</b> Hall Packer machine loaded</p>
	<p><b>Loading Density:</b> gm/cc 0.9 Tamped cartridge 1-1/2" diameter, 8" long</p>
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group A</p> <p>Exudation</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Sensitivity to Initiation:</b> Stick dry, No. 6 Electric cap Positive Stick dry, Corps of Engineers Positive Stick wet, Corps of Engineers Positive</p> <p><b>Air Gap Propagation:</b> Max distance will, inch 2-1/2 min distance will not, inch 3</p> <p><b>Stick Water Immersion:</b> Weight gain, % 9-16</p> <p><b>Heat of:</b> Explosion, cal/gm 625 Gas Volume, cc/gm 611</p> <p><b>Cold Storage:</b> Plastic to -65°F</p> <p><b>Low Temperature Usage:</b> -65°F, 1 day, M2 cap crimper Satisfactory</p>

Preparation:

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

Origin:

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

References: <sup>25</sup>

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

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

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

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

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p><b>Color:</b> Buff</p> <hr/> <p><b>Principal Uses:</b> Excavation, demolition, and cratering</p> <hr/> <p><b>Method of Loading:</b> Hall Packer machine loaded</p> <hr/> <p><b>Loading Density:</b> gm/cc 1.1                  Cartridge 1-1/2" diameter, 8" long</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25 1/2 ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: center;">Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: center;">Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td style="text-align: center;">Group A</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group A	Exudation		
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group A									
Exudation										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Sensitivity to Initiation:</b>                  Stick dry, No. 6 Electric cap Positive                  Stick dry, Corps of Engineers Positive                  Stick wet, Corps of Engineers &gt; 50% Positive</p> <p><b>Air Gap Propagation:</b>                  Max distance will, inch 1                  Min distance will not, inch 2-1/2</p> <p><b>Quarry Performance:</b> 4 tons rock/ton explosive</p> <p><b>Stick Water Immersion:</b>                  Weight gain, % 25-27</p> <p><b>Heat of:</b>                  Explosion, cal/gm 935                  Gas Volume, cc/gm 945</p> <p><b>Cold Storage:</b> Plastic to -70°F</p> <p><b>Low Temperature Usage:</b>                  -65°F, 1 day, M2 cap                  crimper Satisfactory</p>									

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:<sup>26</sup>

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

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

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

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





<b>Composition:</b>		<b>Molecular Weight:</b>	178
%		<b>Oxygen Balance:</b>	
Haleite (Ethylene Dinitramine)	55	CO <sub>2</sub> %	-51
TNT	45	CO %	-17
		<b>Density: gm/cc, Cast</b>	1.62
		<b>Melting Point: °C Eutectic</b>	80
C/H Ratio		<b>Freezing Point: °C</b>	
<b>Impact Sensitivity, 2 Kg Wt:</b>		<b>Boiling Point: °C</b>	
Bureau of Mines Apparatus, cm	95	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b>	
Sample Wt 20 mg		n <sub>D</sub> <sup>25</sup>	
Picotinny Arsenal Apparatus, in.		n <sub>D</sub> <sup>30</sup>	
Sample Wt, mg	20		
<b>Friction Pendulum Test:</b>		<b>Vacuum Stability Test:</b>	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	1.0
<b>Rifle Bullet Impact Test:</b>	Trials	120°C	11+
	%	135°C	
Explosions	0	150°C	
Partials	0		
Burned	7	<b>200 Gram Bomb Sand Test:</b>	
Unaffected	93	Sand, gm	49.4
<b>Explosion Temperature: *</b>	°C	<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	435	Minimum Detonating Charge, gm	
1	248	Mercury Fulminate	0.22*
5 Decomposes	190	Lead Azide	0.26*
10	183	*Alternative initiating charges.	
15	176	<b>Ballistic Mortar, % TNT: (a)</b>	119
20	168	<b>Trouzi Test, % TNT: (b)</b>	120
*Composition Haleite/TNT, 60/40.		<b>Plate Dent Test:</b>	52/48
<b>75°C International Heat Test:</b>		Method	B
% Loss in 48 Hrs		Condition	Cast
<b>100°C Heat Test:</b>		Confined	No
% Loss, 1st 48 Hrs	0.2	Density, gm/cc	1.62
% Loss, 2nd 48 Hrs	0.1	Brisance, % TNT	112
Explosion in 100 Hrs	None	<b>Detonation Rate:</b>	
<b>Flammability Index:</b>	Will not continue to burn	Confinement	None
<b>Hygroscopicity: %</b>	None	Condition	Cast
<b>Volatility:</b>		Charge Diameter, in.	1.0
		Density, gm/cc	1.63
		Rate, meters/second	7340

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b></p> <table border="0"> <tr> <td>Density, gm/cc</td> <td>1.56</td> <td>1.62</td> </tr> <tr> <td>Charge Wt, lb</td> <td>2.065</td> <td>2.092</td> </tr> </table> <p><b>Total No. of Fragments:</b></p> <table border="0"> <tr> <td>For TNT</td> <td>703</td> <td>703</td> </tr> <tr> <td>For Subject HE</td> <td>842</td> <td>902</td> </tr> </table> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <table border="0"> <tr> <td>Density, gm/cc</td> <td></td> <td>1.60</td> </tr> <tr> <td>Charge Wt, lb</td> <td></td> <td>0.845</td> </tr> </table> <p><b>Total No. of Fragments:</b></p> <table border="0"> <tr> <td>For TNT</td> <td></td> <td>514</td> </tr> <tr> <td>For Subject HE</td> <td></td> <td>536</td> </tr> </table>	Density, gm/cc	1.56	1.62	Charge Wt, lb	2.065	2.092	For TNT	703	703	For Subject HE	842	902	Density, gm/cc		1.60	Charge Wt, lb		0.845	For TNT		514	For Subject HE		536	<p><b>Shaped Charge Effectiveness, TNT = 100:</b> <u>50/50</u></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td>126</td> <td>123</td> </tr> <tr> <td>Hole Depth</td> <td>117</td> <td>121</td> </tr> </table> <p><b>Color:</b> Yellow</p> <p><b>Principal Uses:</b> Projectiles, bombs; special ammunition components</p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density: gm/cc</b> 1.65</p>		Glass Cones	Steel Cones	Hole Volume	126	123	Hole Depth	117	121
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<p><b>Blast (Relative to TNT):</b> (d, e)</p> <p><b>Air:</b></p> <table border="0"> <tr> <td>Peak Pressure</td> <td>108</td> </tr> <tr> <td>Impulse</td> <td>110</td> </tr> <tr> <td>Energy</td> <td>108</td> </tr> </table> <p><b>Air, Confined:</b></p> <table border="0"> <tr> <td>Impulse</td> <td></td> </tr> </table> <p><b>Under Water:</b></p> <table border="0"> <tr> <td>Peak Pressure</td> <td>--</td> </tr> <tr> <td>Impulse</td> <td>--</td> </tr> <tr> <td>Energy</td> <td>113</td> </tr> </table> <p><b>Underground:</b></p> <table border="0"> <tr> <td>Peak Pressure</td> <td></td> </tr> <tr> <td>Impulse</td> <td></td> </tr> <tr> <td>Energy</td> <td></td> </tr> </table>	Peak Pressure	108	Impulse	110	Energy	108	Impulse		Peak Pressure	--	Impulse	--	Energy	113	Peak Pressure		Impulse		Energy		<p><b>Eutectic Temperature, °C:</b> 79.8</p> <table border="0"> <tr> <td>gm Halate/100 gm TNT</td> <td></td> </tr> <tr> <td>79.8°C</td> <td>0.48</td> </tr> <tr> <td>95.0°C</td> <td>1.12</td> </tr> </table> <p><b>Compatibility with Metals:</b></p> <p><b>Dry:</b> 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.</p> <p><b>Wet:</b> 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.</p>	gm Halate/100 gm TNT		79.8°C	0.48	95.0°C	1.12							
Peak Pressure	108																																	
Impulse	110																																	
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<p><b>Booster Sensitivity Test:</b> (d)</p> <table border="0"> <tr> <td>Condition</td> <td>Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>100</td> </tr> <tr> <td>Wax in. for 50% Detonation</td> <td>1.28</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.62</td> </tr> </table>	Condition	Cast	Tetryl, gm	100	Wax in. for 50% Detonation	1.28	Density, gm/cc	1.62																										
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Preparation:

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

Origin:

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

References: <sup>28</sup>

(a) L. C. Smith and E. G. 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. See III, Variation of Cavity Effect with Composition, NDRC Contract W-672-ORD-5723.

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

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

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

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

Composition: % C 25.6 H 2.6 N 17.1 O 54.7 C/H Ratio 0.235 $\begin{array}{c} \text{CH}_2\text{CO}_2\text{CH}_2\text{CH}_2\text{C}(\text{NO}_3) \\   \\ \text{CH}_2\text{CO}_2\text{CH}_2\text{CH}_2\text{C}(\text{NO}_3) \end{array}$	Molecular Weight: (C <sub>10</sub> H <sub>12</sub> N <sub>6</sub> O <sub>16</sub> )	468
	Oxygen Balance: CO, % CO %	-34 0
	Density: gm/cc	Crystal 1.63
	Melting Point: °C	96
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>	
Friction Pendulum test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact test: Trials Explosions % Partials Burned Unaffected	200 Gram Bomb Sand test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point 230 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 % Loss, 2nd 48 Hrs Explosion in 100 Hrs		
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	1.63 7340
Hygroscopicity: %		
Volatility:		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm ME, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch Hf, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Color:</b></p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Principal Uses:</b> Casting medium for HE compounds</p>									
	<p><b>Method of Loading:</b> Cast</p>									
	<p><b>Loading Density:</b> gm/cc 1.60</p>									
	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td></td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation	None	
Method	Dry									
Hazard Class (Quantity-Distance)										
Compatibility Group										
Exudation	None									
	<p><b>Preparation:</b> (a)</p> <p>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.</p> <p><b>Origin:</b></p> <p>First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey.</p> <p><b>Viscosity, poises:</b></p> <table> <tr> <td>Temp, 98.9°C</td> <td>0.246</td> </tr> <tr> <td>106.5°C</td> <td>0.193</td> </tr> </table> <p><b>Liquid Density, gm/cc:</b></p> <table> <tr> <td>Temp, 98.9°C</td> <td>1.467</td> </tr> <tr> <td>106.5°C</td> <td>1.459</td> </tr> </table>	Temp, 98.9°C	0.246	106.5°C	0.193	Temp, 98.9°C	1.467	106.5°C	1.459	
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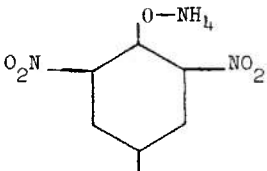
Ethylene Glycol Di-Trinitrobutyrate (GTNB)References:<sup>29</sup>

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

(b) U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, Letter from Dr. O. H. Johnson to Commanding Officer, Picatinny Arsenal, 8 April 1955 (ORDBB 471.86/44-3, Registry No. 39815); and NOL Letter from Dr. D. V. Sickman to Commanding Officer, Picatinny Arsenal, 29 November 1955 (ORDBB 471.86/159-1; Serial No. 02894).

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

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



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>            Density, gm/cc 1.50            Charge Wt, lb 1.94</p> <p><b>Total No. of Fragments:</b>            For TNT 703            For Subject HE 649</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>            Density, gm/cc 1.55            Charge Wt, lb 0.82</p> <p><b>Total No. of Fragments:</b>            For TNT 514            For Subject HE 508</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth											
	Glass Cones	Steel Cones																	
Hole Volume																			
Hole Depth																			
<p><b>Fragment Velocity: ft/sec</b>            At 9 ft            At 25½ ft            Density, gm/cc</p>	<p><b>Color:</b> Yellow-orange</p> <p><b>Principal Uses:</b> AP projectiles and bombs</p>																		
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Air, Confined:</b>            Impulse</p> <p><b>Under Water:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Underground:</b>            Peak Pressure            Impulse            Energy</p>	<p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc      psi x 10<sup>5</sup></p> <table> <thead> <tr> <th></th> <th>3</th> <th>5</th> <th>10</th> <th>12</th> <th>15</th> <th>20</th> </tr> </thead> <tbody> <tr> <td></td> <td>1.33</td> <td>1.41</td> <td>1.47</td> <td>1.49</td> <td>1.51</td> <td>1.53</td> </tr> </tbody> </table> <p><b>Storage:</b></p> <p>Method: Dry</p> <p>Hazard Class (Quantity-Distance): Class 9</p> <p>Compatibility Group: Group I</p> <p>Exudation: None at 65°C</p>		3	5	10	12	15	20		1.33	1.41	1.47	1.49	1.51	1.53				
	3	5	10	12	15	20													
	1.33	1.41	1.47	1.49	1.51	1.53													
	<p><b>Sensitivity to Electrostatic Discharge, Joules:</b> (d)</p> <p><u>Through 100 Mesh:</u></p> <table> <tbody> <tr> <td>Confined</td> <td>6.0</td> </tr> <tr> <td>Unconfined</td> <td>0.025</td> </tr> </tbody> </table> <p><b>Booster Sensitivity Test:</b> (e)</p> <table> <tbody> <tr> <td>Condition</td> <td>Pressed</td> </tr> <tr> <td>Tetryl, gm</td> <td>100</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td>1.27</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.54</td> </tr> </tbody> </table> <p><b>Heat of:</b></p> <table> <tbody> <tr> <td>Combustion, cal/gm</td> <td>2890</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>800</td> </tr> <tr> <td>Formation, cal/gm</td> <td>395</td> </tr> </tbody> </table>	Confined	6.0	Unconfined	0.025	Condition	Pressed	Tetryl, gm	100	Wax, in. for 50% Detonation	1.27	Density, gm/cc	1.54	Combustion, cal/gm	2890	Explosion, cal/gm	800	Formation, cal/gm	395
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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:

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

<u>Water</u>		<u>Alcohol</u>		<u>Ethyl Acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	1.1	0	0.515	0	0.290
100	75	10	0.690	10	0.300
		30	1.050	30	0.380
		50	1.890	50	0.450
		80	3.620	80	0.560

Origin:

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

Destruction by Chemical Decomposition:

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

References: <sup>30</sup>

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

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

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
340	1441	132	a43	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				

Composition: %		Molecular Weight: (C <sub>6</sub> H <sub>9</sub> N <sub>3</sub> O <sub>11</sub> )	299
24.1		Oxygen Balance:	
3.0	$\begin{array}{c} \text{O} \quad \text{ONO}_2 \\ \parallel \quad   \\ \text{CH}_2 - \text{O} - \text{C} - \text{CH} - \text{CH} \end{array}$	CO, %	-30
N 14.1	$\begin{array}{c} \text{CH} - \text{ONO}_2 \\   \\ \text{CH}_2 - \text{ONO}_2 \end{array}$	CO %	3
O 58.8		Density: gm/cc	Liquid 1.47
C/H Ratio 0.180		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 (11b wt); 42 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg		Boiling Point: °C	
		Refractive Index, n <sub>20</sub> <sup>D</sup>	
		n <sub>25</sub> <sup>D</sup>	1.464
		n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	5.9
		120°C	
		135°C	
		150°C	
Rifle Bullet Impact Test: Trials		200 Gram Bomb Sand Test:	
	%	Sand, gm	13.1
Explosions		Explosion Temperature: °C	
Portials		Seconds, 0.1 (no cap used)	
Burned		1	
Unaffected		5	223
		10	
		15	
		20	
75°C International Heat Test:		Sensitivity to Initiation:	
% Loss in 48 Hrs		Minimum Detonating Charge, gm	
		Mercury Fulminate	
		Lead Azide	
		Tetryl	
100°C Heat Test:		Ballistic Mortar, % TNT:	
% Loss, 1st 48 Hrs	2.5	Trauzl Test, % TNT:	
% Loss, 2nd 48 Hrs	1.8	Plate Dent Test:	
Explosion in 100 Hrs	None	Method	
		Condition	
		Density, gm/cc	
		Brisance, % TNT	
Flammability Index:		Detonation Rate:	
		Confinement	
		Condition	
Hygroscopicity: %		Charge Diameter, in.	
		Density, gm/cc	
Volatility: 60°C, mg/cm <sup>2</sup> /hr	28	Rate, meters/second	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td><b>Glass Cones</b></td> <td><b>Steel Cones</b></td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		<b>Glass Cones</b>	<b>Steel Cones</b>	Hole Volume			Hole Depth		
		<b>Glass Cones</b>	<b>Steel Cones</b>							
	Hole Volume									
	Hole Depth									
	<p><b>Color:</b></p>									
<p><b>Principal Uses:</b> Gelatinizer for nitrocellulose</p>										
<p><b>Method of Loading:</b></p>										
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Liquid</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Liquid	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation		
	Method	Liquid								
	Hazard Class (Quantity-Distance)	Class 9								
	Compatibility Group									
	Exudation									
	<p><b>Hydrolysis, % Acid:</b></p> <table> <tr> <td>10 days at 22°C</td> <td>0.021</td> </tr> <tr> <td>5 days at 60°C</td> <td>0.014</td> </tr> </table>	10 days at 22°C	0.021	5 days at 60°C	0.014					
	10 days at 22°C	0.021								
	5 days at 60°C	0.014								
	<p><b>Solubility in Water, gm/100 gm, at:</b></p> <table> <tr> <td>25°C</td> <td>&lt; 0.01</td> </tr> <tr> <td>60°C</td> <td>&lt; 0.015</td> </tr> </table>	25°C	< 0.01	60°C	< 0.015					
	25°C	< 0.01								
60°C	< 0.015									
<p><b>Solubility, gm/100 gm, at 25°C, in:</b></p> <table> <tr> <td>Ether</td> <td>∞</td> </tr> <tr> <td>2:1 Ether:Alcohol</td> <td>m</td> </tr> <tr> <td>Acetone</td> <td>∞</td> </tr> </table>	Ether	∞	2:1 Ether:Alcohol	m	Acetone	∞				
Ether	∞									
2:1 Ether:Alcohol	m									
Acetone	∞									
<p><b>Heat of:</b></p> <table> <tr> <td>Combustion, cal/gm</td> <td>2407</td> </tr> </table>	Combustion, cal/gm	2407								
Combustion, cal/gm	2407									

Preparation:

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

Origin:

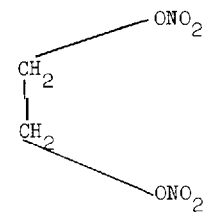
The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

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

Reference:<sup>31</sup>

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

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

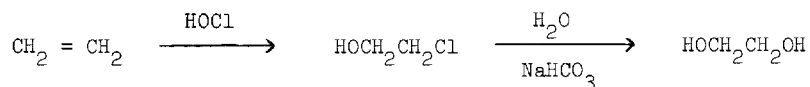
<b>Composition:</b> % C 15.8 H 2.6 N 18.4 O 63.2 C/H Ratio 0.092 	<b>Molecular Weight:</b> ( $C_2H_4N_2O_6$ ) 152
	<b>Oxygen Balance:</b> CO, % 0.0 CO % 21
	<b>Density:</b> gm/cc Liquid, 25°C 1.48
	<b>Melting Point:</b> °C -20
	<b>freezing point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth						
		Glass Cones	Steel Cones											
	Hole Volume													
	Hole Depth													
	<p><b>Color:</b> Yellow</p>													
<p><b>Principal Uses:</b> Ingredient of nonfreezing dynamite</p>														
<p><b>Method of Loading:</b></p>														
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b></p>													
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Liquid</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Liquid	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation						
	Method	Liquid												
	Hazard Class (Quantity-Distance)	Class 9												
	Compatibility Group													
	Exudation													
	<p><b>Solubility in 1000 cc Water:</b></p> <table> <thead> <tr> <th>Temp. °C</th> <th>Grams</th> </tr> </thead> <tbody> <tr> <td>15</td> <td>6.2</td> </tr> <tr> <td>20</td> <td>6.8</td> </tr> <tr> <td>50</td> <td>9.2</td> </tr> </tbody> </table>	Temp. °C	Grams	15	6.2	20	6.8	50	9.2					
	Temp. °C	Grams												
	15	6.2												
	20	6.8												
	50	9.2												
<p><b>Viscosity, centipoises:</b></p> <table> <tr> <td>Temp, 20°C</td> <td>4.2</td> </tr> </table>	Temp, 20°C	4.2												
Temp, 20°C	4.2													
<p><b>Vapor Pressure:</b></p> <table> <thead> <tr> <th>°C</th> <th>mm Mercury</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0.0044</td> </tr> <tr> <td>20</td> <td>0.038</td> </tr> <tr> <td>40</td> <td>0.26</td> </tr> <tr> <td>60</td> <td>1.3</td> </tr> <tr> <td>80</td> <td>5.9</td> </tr> <tr> <td>100</td> <td>22.0</td> </tr> </tbody> </table>	°C	mm Mercury	0	0.0044	20	0.038	40	0.26	60	1.3	80	5.9	100	22.0
°C	mm Mercury													
0	0.0044													
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<p><b>Heat of:</b></p> <table> <tr> <td>Combustion, cal/gm</td> <td>1764</td> </tr> <tr> <td>Formation, cal/gm (b)</td> <td>366</td> </tr> </table>	Combustion, cal/gm	1764	Formation, cal/gm (b)	366										
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<sub>2</sub>CH<sub>2</sub>OH, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:

Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was made of glycol diqitrate 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:<sup>32</sup>

- (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, PAIR 1624, 27 August 1946.

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

Composition: %		Molecular Weight:	93
RDX	45	Oxygen Balance:	
TNT	30	CO %	-36
Aluminum	20	Density: gm/cc	Cast 1.74
D-2 Wax	5	Melting Point: °C	
Calcium Chloride, added	0.5	Freezing Point: °C	
C/H Ratio		Boiling Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm	--	Refractive Index, $n_{20}^D$	
Sample Wt 20 mg		$n_{25}^D$	
Picatinny Arsenal Apparatus, in, (c)	14	$n_{30}^D$	
Sample Wt, mg	18		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	---	90°C	----
Rifle Bullet Impact Test: Trials	(b)	100°C	0.47
	%	120°C	
Explosions	80	135°C	
Partials	--	150°C	
Burned	--	200 Gram Bomb Sand Test:	
Unaffected	20	Sand, gm	49.5
Explosion Temperature: °C (a)		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5	610(min) (c)	Lead Azide	0.20
10		Tetryl	0.10
15		Ballistic Mortar, % TNT: (a)	135
20		Traul Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.78	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	(a, b)
		Confinement	None
Hygroscopicity: % 30°C, 95% RH, 7 days	2.01	Condition	Cast
71°C, 95% RH, 7 days	1.77	Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.71
		Rate, meters/second	7191

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

<p><b>Fragmentation Test:</b> (b)</p> <p><b>90 mm HE, M71 Projectile, Lot EGS-1-17:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For Composition B 998                  For Subject HE 714                  For 80/20 Tritonal 616</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Gray</p>									
<p><b>Blast (Relative to TNT):</b> (a)</p> <p><b>Air:</b> 3.25" diameter sphere                  Peak Pressure Δ psi Catenary 25.4                  Impulse NFOC Pendulum 19.8                  Energy ----</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> HE charge</p>									
	<p><b>Method of Loading:</b> Cast</p>									
	<p><b>Loading Density:</b> gm/cc 1.71</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation	None									

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

(Reference e)

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

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

Average Fragment Velocities at Various Altitudes\* (e)

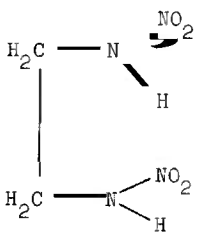
<u>Explosive</u>	<u>Charge Diameter, Inches</u>	<u>Simulated Altitude, Feet</u>			
		<u>Ground</u> m/s	<u>30,000</u> m/s	<u>60,000</u> m/s	<u>90,000</u> m/s
gm/cc 1.51		2940	2991		
H-6, density, gm/cc 1.71	1	3461	3405	3467	3563
	2	4603	4726	4998	5288

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

References:

See HBX-1; HBX-3 reference list.

(In recognition of its development as a military explosive by the

Composition: % C 16.0 H 4.0 N 37.3 O 42.7 C/H Ratio 0.066		Molecular Weight: (C <sub>2</sub> H <sub>6</sub> N <sub>4</sub> O <sub>4</sub> )	150									
		Oxygen Balance:										
		CO, %	-32									
		CO <sup>2</sup> , %	-10.5									
		Density: gm/cc	Crystal 1.71									
Melting Point: °C	Decomposes 175+											
Freezing Point: °C												
Boiling Point: °C												
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 48 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 17	Refractive Index, n <sub>D</sub> <sup>20</sup>											
	n <sub>D</sub> <sup>25</sup>											
	n <sub>D</sub> <sup>30</sup>											
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability test: cc/40 Hrs, at 90°C	100°C	0.5									
		120°C	1.5									
Rifle Bullet Impact Test: <table border="1" style="display: inline-table; vertical-align: top;"> <thead> <tr> <th>Trials</th> <th>%</th> </tr> </thead> <tbody> <tr> <td>Explosions</td> <td>0</td> </tr> <tr> <td>Partials</td> <td>60</td> </tr> <tr> <td>Burned</td> <td>20</td> </tr> <tr> <td>Unaffected</td> <td>20</td> </tr> </tbody> </table>	Trials	%	Explosions	0	Partials	60	Burned	20	Unaffected	20	135°C	--
	Trials	%										
	Explosions	0										
	Partials	60										
Burned	20											
Unaffected	20											
	150°C	11+										
	200 Gram Bomb Sand Pest:											
	Sand, gm	52.3										
Explosion Temperature: °C Seconds, 0.1 (no cap used) 265 1 216 5 Decomposes 189 10 178 15 173 20 170	Sensitivity to Initiation:											
	Minimum Detonating Charge, gm											
	Mercury Fulminate	0.21										
	Lead Azide	0.13										
	Tetryl	--										
	Ballistic Mortar, % TNT: (a)	139										
75°C International Heat Test:	TraurI Test, % TNT: (b)	122										
% Loss in 48 Hrs 0.01	Plate Dent Test: (c)											
100°C Heat Test: % Loss, 1st 48 Hrs 0.2 % Loss, 2nd 48 Hrs 0.3 Explosion in 100 Hrs None	Method	A										
	Condition	Pressed										
	Confined	Yes										
	Density, gm/cc	1.50										
Flammability Index: 138	Brisance, % TNT	122										
	Detonation Rate:											
Hygroscopicity: % 0.01	Confinement	Unconfined										
	Condition	Pressed										
Volatility: Nil	Charge Diameter, in.	1.0										
	Density, gm/cc	1.49										
	Rate, meters/second	7570										

<p>Booster Sensitivity Test: Condition (d) Pressed</p> <p>Tetryl, gm 100</p> <p>Wax, in. for 50% Detonation 2.09</p> <p>Wax, gm</p> <p>Density, gm/cc 1.42</p>	<p>Decomposition Equation: (e) (e) (f)</p> <p>Oxygen, atoms/sec <math>10^{12.8}</math> <math>10^{12.1}</math> <math>10^{11.1}</math></p> <p>(Z/sec)</p> <p>Heat, kilocalorie/mole 30.5 37.3 30.8</p> <p>(ΔH, kcal/mol)</p> <p>Temperature Range, °C 184-254 -- 144-164</p> <p>Phase Liquid Solid Solid</p>
<p>Heat of:</p> <p>Combustion, cal/gm 2477</p> <p>Explosion, cal/gm 1276</p> <p>Gas Volume, cc/gm 908</p> <p>Formation, cal/gm 134</p> <p>Fusion, cal/gm</p>	<p>Armor Plate Impact Test:</p> <p>60 mm Mortar Projectile:</p> <p>50% Inert, Velocity, ft/sec</p> <p>Aluminum Fineness</p> <p>500-lb General Purpose Bombs:</p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>
<p><b>Specific Heat:</b> cal/gm/°C</p>	<p>Bomb Drop Test:</p> <p>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft</p> <p>500-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p>1000-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>
<p>Burning Rate: cm/sec</p>	
<p>Thermal Conductivity: cal/sec/cm/°C</p>	
<p>Coefficient of Expansion: Linear, %/°C</p> <p>Volume, %/°C</p>	
<p>Hardness, Mohs' Scale:</p>	
<p>Young's Modulus: E, dynes/cm<sup>2</sup></p> <p>E, lb/inch<sup>2</sup></p> <p>Density, gm/cc</p>	
<p>Compressive Strength: lb/inch<sup>2</sup></p>	
<p>Vapor Pressure: °C mm Mercury</p>	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.61                  Charge Wt, lb --</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc <u>95/5 Haleite/wax</u> 1.56                  Charge Wt, lb --</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 600</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume                  Hole Depth</p>										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> White</p>										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Booster</p>										
	<p><b>Method of Loading:</b> Pressed</p>										
	<p><b>Loading Density:</b> gm/cc      psi x 10<sup>3</sup></p> <table border="1" style="width: 100%; text-align: center;"> <tr> <td>5</td> <td>10</td> <td>12</td> <td>15</td> <td>20</td> </tr> <tr> <td>1.28</td> <td>1.38</td> <td>1.41</td> <td>1.44</td> <td>1.49</td> </tr> </table>	5	10	12	15	20	1.28	1.38	1.41	1.44	1.49
5	10	12	15	20							
1.28	1.38	1.41	1.44	1.49							
	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group</p> <p>Exudation None</p>										



Compatibility with Metals:

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

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

Impact Sensitivities of Various Crystal Habits:

Bureau of Mines Impact Test, 2 Kg Wt:

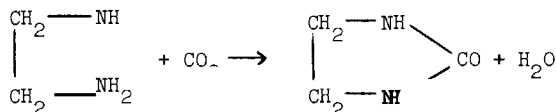
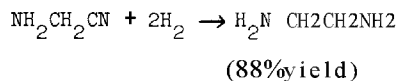
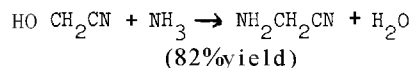
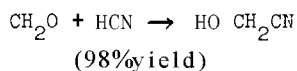
<u>Habit</u>	<u>cm</u>
1st plate	55
2nd plate	55
Bi-pyramid	71
Bracydome	66
Sphenoid	46

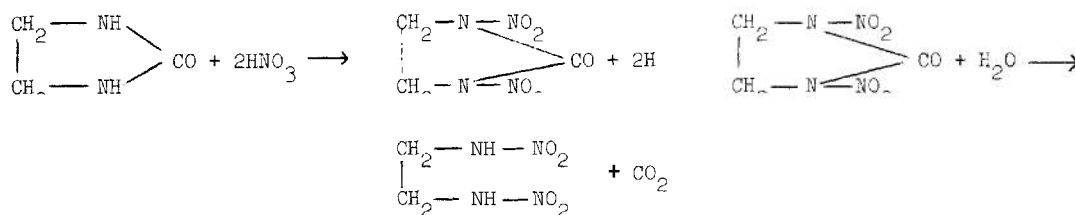
Solubility: gm/100 gm (%) of:

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

Preparation:

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



Haleite (Ethylene Dinitramine) (EDNA)

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

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

Origin:

First described in 1877 by Franchimont and 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: <sup>33</sup>

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

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

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

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

Composition: %		Molecular Weight:	102
RDX	40	Oxygen Balance:	
TNT	38	CO, %	-68
Aluminum	17	CO %	-35
D-2 Wax	5	Density: gm/cc	Cast 1.72
Calcium Chloride, added	0.5	Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	--	Refractive Index, $n_{20}^{\circ}$	
Sample Wt 20 mg		$n_{25}^{\circ}$	
Picatinny Arsenal Apparatus, in.	16	$n_{30}^{\circ}$	
Sample Wt, mg	21		
Friction Pendulum Test: (b)		Vacuum Stability Test:	(a, b)
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	---	90°C	----
Rifle Bullet Impact Test: Trials (b)		100°C	0.47
Explosions	73	120°C	0.98
Partials	--	135°C	----
Burned	--	150°C	11+
Unaffected	28	200 Gram Bomb Sand Test:	
Explosion Temperature: °C (a)		Sand, gm	48.1
Seconds, 0.1 (no cap used)	---	Sensitivity to Initiation:	
1	---	Minimum Detonating Charge, gm	
5	480	Mercury Fulminate	----
10		Lead Azide	0.20
15		Tetryl	0.10
20		Ballistic Mortar, % TNT: (d)	133
75°C International Heat Test:		Trauzl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test:	
100°C Heat Test: (b)		Method	
% Loss, 1st 48 Hrs	0.058	Condition	
% Loss, 2nd 48 Hrs	0.00	Confined	
Explosion in 100 Hrs	None	Density, gm/cc	
Flammability Index:		Brisance, % TNT	
Hygroscopicity: % 30°C, 95% RH, 7 days	2.98	Detonation Rate: (a, b)	
71°C, 95% RH, 7 days	1.13	Confinement	None
Volatility:		Condition	Cast
		Charge Diameter, in.	1.0
		Density, gm/cc	1.69
		Rate, meters/second	7224

Booster Sensitivity Test: (c) Condition Cast Tetryl, gm 100 Wax, in. for 50% Detonation 1.25 Wax, gm Density, gm/cc 1.73	Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (AH, kcal/mole) Temperature Range, °C Phase
Heat of: (b) Combustion, cal/gm 3882 Explosion, cal/gm 919 Gas Volume, cc/gm Formation, cal/gm 758 Fusion, cal/gm 78°C 9.25	Armor Plate Impact Test:  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness  500-lb General Purpose Bombs:  Plate Thickness, inches  1 1¼ 1½ 1¾
Specific Heat: cal/gm/°C (b) 30°C 0.249 50°C 0.264	
Burning Rate: cm/sec	
Thermal Conductivity: (b) cal/sec/cm/°C 35°C 0.97 x 10 <sup>-3</sup>	
Coefficient of Expansion: (b) Linear, ΔL/Δinch 0°C 46 x 10 <sup>-4</sup> 35°C 95 x 10 <sup>-4</sup> 70°C 159 x 10 <sup>-4</sup>	
Hardness, Mohs' Scale:	
Young's Modulus: (b) E, dynes/cm <sup>2</sup> 10.3 x 10 <sup>9</sup> E, lb/inch <sup>2</sup> 1.49 x 10 <sup>5</sup> Density, gm/cc 1.69	
Compressive Strength: lb/inch <sup>2</sup> See below	
Vapor Pressure: °C mm Mercury Compressive Strength: lb/inch <sup>2</sup> (b) 1303 Density, gm/cc 1.69 Ultimate deformation, % 1.38	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

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

<b>Composition:</b> % RDX 31 TNT 29 Aluminum 35 D-2 Wax 5 Calcium Chloride, added 0.5 C/H Ratio	Molecular Weight: 64	
	Oxygen Balance: CO <sub>2</sub> % -75 CO % -49	
	Density: gm/cc	Cast 1.84
	Melting Point: °C	
	Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 23	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe ---	Vacuum Stability test: (a, b) cc/40 Hrs, at 90°C ---- 100°C 0.45 120°C 135°C 150°C	
	<b>Rifle Bullet Impact test:</b> Trials (b) % Explosions 78 Partials -- Burned -- Unaffected 22	200 Gram Bomb Sand test: (b) Sand, gm 44.9
<b>Explosion Temperature:</b> °C (a) Seconds, 0.1 (no cap used) --- 1 --- 5 500 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.10	
	Ballistic Mortar, % TNT: (a) 111	
	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: (b) % Loss, 1st 48 Hrs 0.70 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Detonation Rate: (a, b) Confinement None Condition Cast Charge Diameter, in. 1.0 Density, gm/cc 1.81 Rate, meters/second 6917	
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> % 30°C, 95% RH, 7 days 2.01 (b) 71°C, 95% RH, 7 days 0.31		
<b>Volatility:</b>		

<p><b>Booster Sensitivity Test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (AH, kcal/mol)                  Temperature Range, °C                  Phase</p>
<p><b>Heat of:</b>                  Combustion, cal/gm (b) 4495                  Explosion, cal/gm 877                  Gas Volume, cc/gm                  Formation, cal/gm 491                  Fusion, cal/gm 9.30</p>	<p><b>Armor Plate Impact Test:</b>                   60 mm Mortar Projectile:                  50% Inert, Velocity, ft/sec                  Aluminum Fineness                   500-lb General Purpose Bombs:                   Plate Thickness, inches                  1                  1¼                  1½                  1¾</p>
<p><b>Specific Heat: cal/gm/°C</b>                  30°C 0.254                  50°C 0.254</p>	
<p><b>Burning Rate:</b>                  cm/sec</p>	<p><b>Bomb Drop Test:</b>                   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</p>
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C 35°C (b) 1.70 x 10<sup>-3</sup></p>	
<p><b>Coefficient of Expansion:</b>                  Linear, ΔL/inch (b)                  0°C 40 x 10<sup>-4</sup>                  35°C 83 x 10<sup>-4</sup>                  70°C 130 x 10<sup>-4</sup></p>	
<p><b>Hardness, Mohs' Scale:</b></p>	
<p><b>Young's Modulus:</b>                  E, dynes/cm<sup>2</sup> (b) 11.5 x 10<sup>9</sup>                  E, lb/inch<sup>2</sup> 1.67 x 10<sup>5</sup>                  Density, gm/cc 1.81</p>	
<p><b>Compressive Strength: lb/inch<sup>2</sup></b> See below</p>	
<p><b>Vapor Pressure:</b>                  °C mm Mercury</p>	
<p><b>Compressive Strength: lb/inch<sup>2</sup></b> 1610                  Density, gm/cc 1.81                  Ultimate deformation, % 1.37</p>	



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

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

<u>Explosive Composition</u>	<u>Moisture, %</u>	<u>Acidity, %</u>	<u>100° C Vac Stab Test</u>		<u>Hygroscopicity, %</u>	
			<u>cc gas</u>	<u>Hours</u>	<u>95% RH</u>	
					<u>30°C</u>	<u>71°C</u>
<u>Standard HBX-1</u>	0.73	0.011	0.47	40	+2.98	+1.13
+0.2% moisture			0.68	40		
+0.4% moisture			0.62	40		
+0.6% moisture			0.50	40		
<u>HBX-1 without CaCl<sub>2</sub></u>	0.00	0.029	0.36	40	-0.06	-0.25
+0.2% moisture			0.25	40		
+0.4% moisture			0.23	40		
+0.6% moisture			0.27	40		
<u>HBX-1 with silica gel</u>	0.06	0.031	0.73	40	+0.08	+0.04
<u>Standard HBX-3</u>	0.54	0.012	0.45	40	+2.01	+0.31
+0.2% moisture			0.47	40		
+0.4% moisture			0.43	40		
+0.6% moisture			0.41	40		
<u>HBX-3 without CaCl<sub>2</sub></u>	0.02	0.049	0.46	40	-0.06	-0.29
+0.2% moisture			0.26	40		
+0.4% moisture			0.26	40		
+0.6% moisture			0.20	40		
<u>HBX-3 with silica gel</u>	0.04	0.100	0.45	40	+0.09	+0.05
<u>Standard H-6</u>	0.71	0.017	0.47	40	+2.01	+1.77
+0.2% moisture			0.88	40		
+0.4% moisture			0.63	40		
+0.6% moisture			0.65	40		
<u>H-6 without CaCl<sub>2</sub></u>	0.03	0.082	0.40	40	-0.06	-0.25
+0.2% moisture			0.10	40		
+0.4% moisture			0.25	40		
+0.6% moisture			0.23	40		
<u>H-6 with silica gel</u>	0.05	0.028	0.43	40	+0.09	+0.06

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

HBX-1; HBX-3Preparation:

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

Origin:

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

References:<sup>34</sup>

- (a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Metal Additives, PAIR 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, PAIR 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.

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

<b>Composition:</b> % Potassium Perchlorate (17 microns) 32 Aluminum, atomized (20 microns) 48 RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4  C/H Ratio		Molecular Weight: 47.6  Oxygen Balance: CO <sub>2</sub> % -42 CO % -14  Density: gm/cc, Apparent Pressed at 20,000 psi 1.39 2.1 Melting Point: °C  Freezing Point: °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 16 Sample Wt, mg 24		Boiling Point: °C  Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Detonates Fiber Shoe Unaffected		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 1.25 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partials Burned Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm 12.5
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) --- 1 --- 5 520 10 15 20		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.25
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		Ballistic Mortar, % TNT: Trauzl Test, % TNT:
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
Flammability Index:		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Hygroscopicity: % None		
Volatility: None		

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE	<b>Shaped Charge Effectiveness, TNT = 100:</b>  Glass Cones      Steel Cones Hole Volume Hole Depth																				
	<b>Color:</b> Gray																				
	<b>Principal Uses:</b> HE filler for small caliber projectiles																				
	<b>Method of Loading:</b> Pressed																				
	<b>Loading Density:</b> gm/cc Pressed at 20,000 psi      2.1																				
<b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Storage:</b>  Method      Dry  Hazard Class (Quantity-Distance)  Compatibility Group  Exudation      None																				
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Enerav	<b>Static Tests:</b> <u>20 mm T215E1 Projectile:</u> PA Peak Pressure, psi      55 NFOC 20" Blast Cube      44 ARG 24" Blast Cube      44  <b>Static Tests:</b> <u>20 mm MD7 Projectile:</u> <table border="0"> <tr> <td></td> <td><u>HEX-24</u></td> <td><u>Tritonal</u></td> <td><u>Torpex</u></td> </tr> <tr> <td>Foxboro psi</td> <td>19</td> <td>12.4</td> <td>13.0</td> </tr> <tr> <td>Catenary psi</td> <td>46</td> <td>----</td> <td>----</td> </tr> <tr> <td>Duration, microsec</td> <td>533</td> <td>----</td> <td>----</td> </tr> <tr> <td>ARG 24" Blast Cube</td> <td>36</td> <td>24</td> <td>32</td> </tr> </table>		<u>HEX-24</u>	<u>Tritonal</u>	<u>Torpex</u>	Foxboro psi	19	12.4	13.0	Catenary psi	46	----	----	Duration, microsec	533	----	----	ARG 24" Blast Cube	36	24	32
	<u>HEX-24</u>	<u>Tritonal</u>	<u>Torpex</u>																		
Foxboro psi	19	12.4	13.0																		
Catenary psi	46	----	----																		
Duration, microsec	533	----	----																		
ARG 24" Blast Cube	36	24	32																		
Flame Temperature, °K      2552 Activation Energy, kcal      20.4 Temp, °C      450 to 570 Specific reaction rate, k      1.64 x 10 <sup>-5</sup>	<b>Heat of:</b>  Combustion, cal/gm      4197 Explosion, cal/gm      1858 Gas volume, cc/gm      159																				

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> Gray</p> <p><b>Principal Uses:</b> HE filler for small caliber projectiles</p> <p><b>Method of Loading:</b> Pressed</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																			
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<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc                  Pressed at 20,000 psi 1.62</p> <p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>																										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Static Tests:</b>  <u>20 mm T215E1 Projectile:</u>                  PA Peak Pressure, psi 77                  NFOC 20" Blast Cube 45                  APG 24" Blast Cube 42</p> <p><b>Static Tests:</b>  <u>20 mm M97 Projectile:</u></p> <table border="0"> <tr> <td></td> <td>HEX-48</td> <td>TNT</td> <td>Tetryl</td> </tr> <tr> <td>Fosboro psi</td> <td>17.3</td> <td>2.8</td> <td>3.5</td> </tr> <tr> <td>Catenary-psi</td> <td>43</td> <td>28</td> <td>28</td> </tr> <tr> <td>Duration, microsec</td> <td>517</td> <td>560</td> <td>530</td> </tr> <tr> <td>APG 24" Blast Cube</td> <td>29</td> <td>---</td> <td>10</td> </tr> </table> <p><b>Heat of:</b></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>4119</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1735</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>200</td> </tr> </table>		HEX-48	TNT	Tetryl	Fosboro psi	17.3	2.8	3.5	Catenary-psi	43	28	28	Duration, microsec	517	560	530	APG 24" Blast Cube	29	---	10	Combustion, cal/gm	4119	Explosion, cal/gm	1735	Gas Volume, cc/gm	200
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<p><u>Flame Temperature, °K</u> 2382</p> <p><u>Activation Energy, kcal</u> 25.4</p> <p><u>Temp, °C</u> 450 to 470</p> <p><u>Specific reaction rate, k</u> <math>7.84 \times 10^{-6}</math></p>																											

Cook-Off Tests: (c)

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

Projectile No	Cook-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:

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Projectile	Filler	Altitude, Feet	Avg. No. of Penetrations per Round in Zone 65°-130°		
			0.020"	0.040"	0.051"
T215E1	HEX-48	Ground	352	264	282
		60,000	676	432	388

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.



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

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

Origin:

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

References:<sup>35</sup>

(a) O. E. Sheffield and E. J. Murray, Development of Explosives—Metalized Explosives—High Blast Fillers for Small Caliber Shell, Picatinny Arsenal Memorandum Report No. MR-49, 21 December 1953.

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

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

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

Composition: % C 33.0 H 1.2 N 21.9 O 43.9 C/H Ratio 0.797		Molecular Weight: (C <sub>14</sub> H <sub>6</sub> N <sub>8</sub> O <sub>14</sub> ) Oxygen Balance: CO, % -53.4 CO <sub>2</sub> , % -9.4 Density: gm/cc Melting Point: °C Decomposes 302 Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 15 Sample Wt, mg 12	Boiling Point: °C Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	Friction Pendulum test: Steel Shoe Unaffected Fiber Shoe Unaffected
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.40 120°C 135°C 150°C	200 Gram Bomb Sand Test: Sand, gm 52.1
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 384 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.30 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	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
100°C Heat Test: % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None	Flammability Index:	
Hygroscopicity: % 25°C, 90% RH 0.19	Volatility:	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Almost white</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Igniter powder; pyrotechnic compositions</p>									
	<p><b>Method of Loading:</b> Pressed and extruded</p>									
	<p><b>Loading Density:</b> gm/cc</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group										
Exudation	None									

Solubility in the following substances:

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

Preparation:

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

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

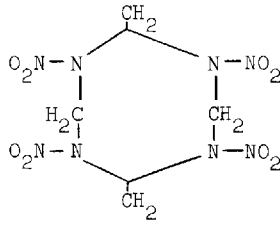
Origin:

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

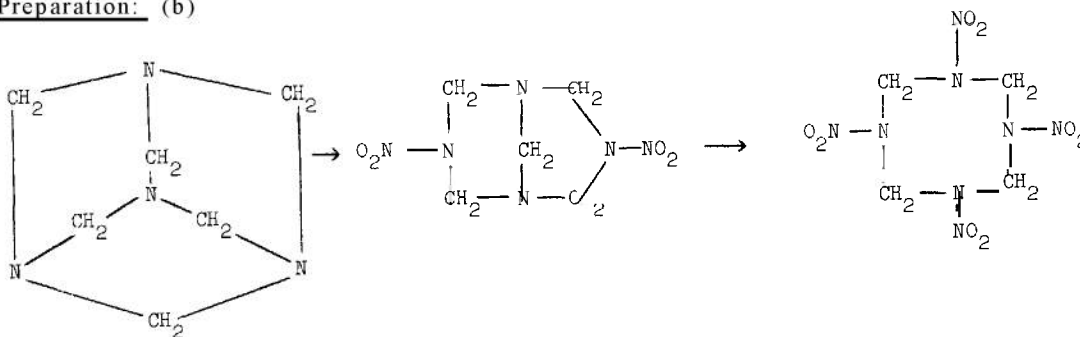
References: <sup>36</sup>

- (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, PAIR No. 2267, July 1956.

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

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

<p>Booster Sensitivity Test:                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p>Decomposition Equation: (e)                  Oxygen, atoms/sec <math>10^{19.7}</math>                  (Z/sec)                  Heat, kilocalorie/mole 52.7                  (AH, kcal/mol)                  Temperature Range, °C 271-314                  Phase Liquid</p>														
<p>Heat of:                  Combustion, cal/gm 2362                  Explosion, cal/gm (e) 1356                  Gas Volume, cc/gm                  Formation, cal/gm (e) -60.5                  Fusion, cal/gm</p>	<p>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</p>														
<table border="1"> <thead> <tr> <th>Specific Heat: cal/gm/°C</th> <th>Recrystallized (g)</th> </tr> <tr> <th>°C</th> <th>°C</th> </tr> </thead> <tbody> <tr> <td>-75 0.153</td> <td>85 0.288</td> </tr> <tr> <td>0 0.228</td> <td>90 0.290</td> </tr> <tr> <td>25 0.248</td> <td>100 0.295</td> </tr> <tr> <td>50 0.266</td> <td>125 0.307</td> </tr> <tr> <td>75 0.282</td> <td>150 0.315</td> </tr> </tbody> </table>	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	<p>Bomb Drop Test:                   17, 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</p>
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<p>Thermal Conductivity:                  col/sec/cm/°C</p>															
<p>Coefficient of Expansion:                  Linear, %/°C                   Volume, %/°C</p>															
<p>Hardness' Mohs' Scale: (e) 2.3</p>															
<p>Young's Modulus:                  E, dynes/cm²                  E, lb/inch²                  Density, gm/cc</p>															
<p>Compressive Strength: lb/inch²</p>															
<p>Vapor Pressure:                  °C mm Mercury</p>															

Preparation: (b)

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

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

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

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

Origin:

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

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

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		<u>2.24%</u>
Total		100.00%

Various samples were analyzed for RDX content:

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

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

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

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

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



Color:

White

Storage:

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

References: <sup>37</sup>

- (a) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Kanouse, Properties of HMX, PA Chemical Research Laboratory Report No. 52-TML-23, 7 April 1952.
- (b) W. E. Bachmann, The Preparation of HMX, OSRD Report No. 1981, 3 November 1943.
- (c) S. Livingston, Characteristics of Explosives HMX and DPMN, PAIR 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:
- |          |          |          |          |              |
|----------|----------|----------|----------|--------------|
| <u>1</u> | <u>3</u> | <u>6</u> | <u>7</u> | <u>9</u>     |
| 1741     | 2183     | 2016     | 1737     | 1709<br>2059 |
- (g) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PAIR No. 2504, January 1959.

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

Composition:			Molecular Weight:	91
%			Oxygen Balance:	
HMX	49		CO <sub>2</sub> %	-51
TNT	29		CO %	-27
Aluminum	22		Density: gm/cc	Cast 1.90
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 <sub>20</sub> <sup>D</sup>	
Sample Wt 20 mg			n <sub>25</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in.	17		n <sub>30</sub> <sup>D</sup>	
Sample Wt, mg	25			
Friction Pendulum Test:			Vacuum Stability Test:	
Steel Shoe	Unaffected		cc/40 Hrs, at	
Fiber Shoe	Unaffected		90°C	----
			100°C	----
Rifle Bullet Impact Test: 10 Trials, %			120°C	0.37
	<u>3/16" Steel</u>	<u>1/8" Al</u>	135°C	
Explosions	90	50	150°C	
Partials	--	--		
Burned	10	--	200 Gram Bomb Sand Test:	
Unaffected	0	50	Sand, gm	61.3
Explosion Temperature:	°C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---		Minimum Detonating Charge, gm	
1	---		Mercury Fulminate	----
5	Flames erratically	370	Lead Azide	0.30
10			Tetryl	----
15			Ballistic Mortar, % TNT:	120
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: %			Condition	Cast
			Charge Diameter, in.	1.0
Volatility:			Density, gm/cc	1.90
			Rate, meters/second	7866



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

Modulus of Elasticity: \*

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

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

Setback Sensitivity Test: (a)

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

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

Preparation:

Procedure similar to that used for Torpex.

References: <sup>38</sup>

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

(b) R. Brown and R. Velicky, Heat Capacity of HTA-3, Picatinny Arsenal General Laboratory Report No. 58-H1-509, 5 May 1958.

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



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> White-buff</p> <p><b>Principal Uses:</b> Detonators, priming compositions, and commercial blasting caps</p> <p><b>Method of Loading:</b> Pressed</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																								
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Hole Volume																																
Hole Depth																																
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc      psi x 10<sup>3</sup></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">3</td> <td style="text-align: center;">5</td> <td style="text-align: center;">10</td> <td style="text-align: center;">15</td> </tr> <tr> <td></td> <td style="text-align: center;">2.62</td> <td style="text-align: center;">2.71</td> <td style="text-align: center;">2.96</td> <td style="text-align: center;">3.07</td> </tr> </table>		3	5	10	15		2.62	2.71	2.96	3.07																					
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0		0.110																														
25		0.110																														
50		0.110																														

Compatibility with Metals:

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

Wet: Copper and zinc are rapidly attacked by moist lead azide, while aluminum is not attacked in 24 hours. Monel, chrome-nickel and Inconel are not attacked by lead azide ( $\frac{1}{2}\%$  moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-aluminum alloy is very slightly corroded.

<u>Sample Tested</u>	<u>Lead Azide Dry</u>	<u>Lead Azide plus 25% Water</u>	<u>Lead Azide plus 20% Water</u>	<u>Lead Azide plus 20% Ethyl Albu-</u>
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Friction Pendulum Test:

(All IA dextrinated)

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

Impact Sensitivity, 2 Kg Wt:

(All IA dextrinated)

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

Kcal/mole	23.74
Induction Period, seconds	0.5-10

Initiating Efficiency, Grams Required to Give Complete Initiations of:

	<u>Dextrinated Azide (gm)</u>
TNT	0.25
Tetryl	0.10
RDX	0.05
PEIN	0.02

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

0.0070

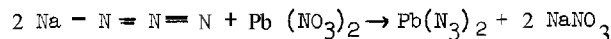


Compatibility of Dextrinated Lead Azide with Black Powder:100°C Vacuum Stability Test, cc/40 hr:

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

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

<u>°C</u>	<u>%</u>
20	0.05

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

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

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

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronimus (French Patent 384,792) should be credited with the first attempt in 1907 to use lead azide with some success in the explosive industry. Its commercial manufacture started in Europe before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead azide can be decomposed by

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

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

(3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 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: <sup>39</sup>

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

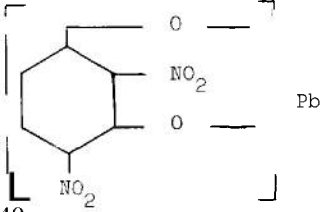
(b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RT 3852, 1946.

(c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR #2224, November 1955.

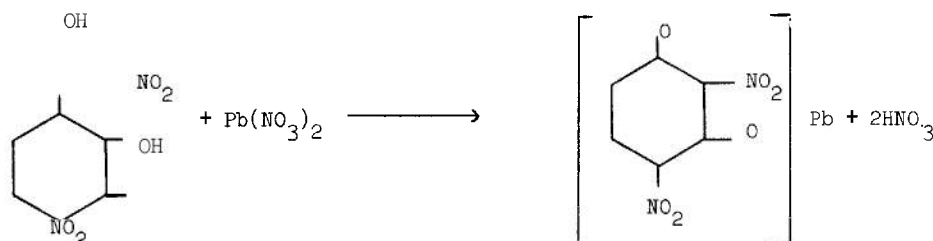
(d) Also see the following Picatinny Arsenal Technical Reports on Lead Azide:

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

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

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
		Glass Cones	Steel Cones							
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	Hole Depth									
	<p><b>Color:</b></p> <p>Red or yellow</p>									
<p><b>Principal Uses:</b></p> <p>Electric detonators</p>										
<p><b>Method of Loading:</b></p> <p>Pressed</p>										
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Wd</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wd	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
	Method	Wd								
	Hazard Class (Quantity-Distance)	Class 9								
	Compatibility Group									
	Exudation	None								
	<p><b>Initiating Efficiency:</b> 0.4 gm LDNR does not initiate tetryl pressed at 3000 psi.</p>									
	<p><b>Heat of:</b></p> <table> <tr> <td>Explosion, cal/gm</td> <td>270</td> </tr> </table>	Explosion, cal/gm	270							
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 11, 323). The lead salt of 2,4-dinitroresorcino1 appears to have been prepared between World War I and World War II by treating resorcino1 with nitrous acid and oxidizing the resulting dinitrosoresorcino1 to dinitroresorcino1. Lead nitrate solution was then added to a solution of the 2,4-dinitroresorcino1 to which sodium carbonate had been added to form the soluble sodium salt (J. D. Hopper, PAIR 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, PAIR 1448, September 1944).

References: <sup>40</sup>

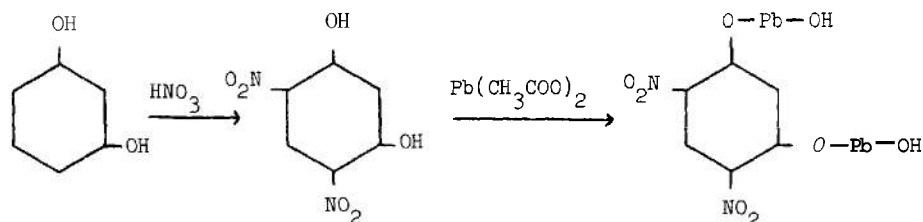
(a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

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

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

<b>Composition:</b> % C 11.2 H 0.6 N 4.3 O 19.8 Pb 64.1  C/H Ratio 0.177		<b>Molecular Weight:</b> (Pb <sub>2</sub> C <sub>6</sub> H <sub>4</sub> N <sub>2</sub> O <sub>8</sub> ) 646
		<b>Oxygen Balance:</b> CO, % -20 CO <sub>2</sub> % -5
		<b>Density:</b> gm/cc
		<b>Melting Point:</b> °C 213
		<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm 1 kg wt 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20	<b>Boiling Point:</b> °C	
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Refractive Index, n<sub>D</sub><sup>D</sup></b> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partial Burned Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 Explodes 295 10 15 20	<b>200 Gram Bomb Sand Test:</b> Sand gm Black powder fuse 15	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Teteryl	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None	<b>Ballistic Mortar, % TNT:</b>	
<b>Flammability Index:</b>	<b>TraurI Test, % TNT:</b>	
<b>Hygroscopicity:</b> %	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
<b>Volatility:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Red or yellow</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Electric detonators</p>									
	<p><b>Method of Loading:</b> Pressed</p>									
	<p><b>Loading Density: gm/cc</b></p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None	
Method	Wet									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group										
Exudation	None									
	<p><b>Initiating Efficiency:</b> 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 psi.</p>									

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  $-20^{\circ}\text{C}$ , 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  $50^{\circ}\text{C}$ , 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).

(h) 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.

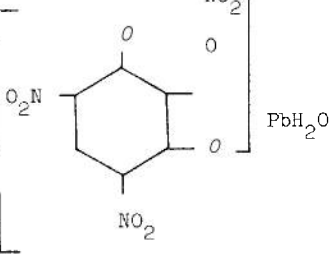
(c) A 0.0278 mole (5.56 grams) quantity of the 4,6-DNR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to  $90^{\circ}\text{C}$ , the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in **small** portions. Agitation is continued for three hours at  $90^{\circ}\text{C}$ . 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:

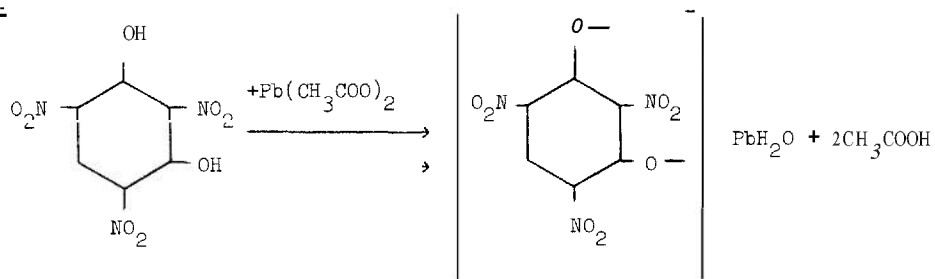
Roth the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M **11**, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin diacetate (Ber **16**, 551). A more direct and economical method of preparation suitable 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  $90^{\circ}\text{C}$ . 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 Sty-phnate

<p>Composition:</p> <table border="0"> <tr><td>%</td><td></td><td></td></tr> <tr><td>C</td><td>15.4</td><td></td></tr> <tr><td>H</td><td>0.6</td><td></td></tr> <tr><td>N</td><td>9.0</td><td></td></tr> <tr><td>O</td><td>30.8</td><td></td></tr> <tr><td>Pb</td><td>44.2</td><td></td></tr> </table> <p>C/H Ratio 0.320</p> 	%			C	15.4		H	0.6		N	9.0		O	30.8		Pb	44.2		<table border="0"> <tr><td>Molecular Weight: (PbC<sub>6</sub>H<sub>3</sub>N<sub>3</sub>O<sub>6</sub>)</td><td>468</td></tr> <tr><td>Oxygen Balance:</td><td></td></tr> <tr><td>CO<sub>2</sub> %</td><td>-19</td></tr> <tr><td>CO %</td><td>2</td></tr> <tr><td>Density: gm/cc</td><td>Crystal</td><td>3.02</td></tr> <tr><td>Melting Point: °C</td><td>Explodes</td><td>260-310</td></tr> <tr><td>Freezing Point: °C</td><td></td><td></td></tr> <tr><td>Boiling Point: °C</td><td></td><td></td></tr> <tr><td>Refractive Index, n<sub>20</sub><sup>D</sup></td><td></td><td></td></tr> <tr><td>n<sub>25</sub><sup>D</sup></td><td></td><td></td></tr> <tr><td>n<sub>30</sub><sup>D</sup></td><td></td><td></td></tr> </table>	Molecular Weight: (PbC <sub>6</sub> H <sub>3</sub> N <sub>3</sub> O <sub>6</sub> )	468	Oxygen Balance:		CO <sub>2</sub> %	-19	CO %	2	Density: gm/cc	Crystal	3.02	Melting Point: °C	Explodes	260-310	Freezing Point: °C			Boiling Point: °C			Refractive Index, n <sub>20</sub> <sup>D</sup>			n <sub>25</sub> <sup>D</sup>			n <sub>30</sub> <sup>D</sup>		
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<p>Hygroscopicity: % 25°C, 100% RH</p> <table border="0"> <tr><td></td><td>0.05</td></tr> <tr><td>30°C, 90% RH</td><td>0.02</td></tr> </table>		0.05	30°C, 90% RH	0.02	<p>Charge Diameter, in.</p> <table border="0"> <tr><td>Density, gm/cc</td><td>2.9</td></tr> </table>	Density, gm/cc	2.9																																									
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30°C, 90% RH	0.02																																															
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<p>Volatility:</p>	<p>Rate, meters/second</p> <table border="0"> <tr><td></td><td>5200</td></tr> </table>		5200																																													
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<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>	
	<p><b>Color:</b>                      Orange-reddish brown</p>	
	<p><b>Principal Uses:</b> Igniting charge, and ingredient of priming compositions</p>	
	<p><b>Method of Loading:</b>                      Pressed</p>	
	<p><b>Loading Density:</b> gm/cc</p>	
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method                                      Wet</p> <p>Hazard Class (Quantity-Distance)      Class 9</p> <p>Compatibility Group                      Group M (wet)</p> <p>Exudation                                      None</p>	
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><u>Heat of:</u></p> <p>Combustion, cal/gm                      1251 Explosion, cal/gm                          457 Gas Volume, cc/gm                      368 Formation, cal/gm                        -92</p>	<p><u>Activation Energy:</u></p> <p>kcal/mol                                      75.39 Induction Period, sec                      0.5-10</p> <p><u>Specific Heat:</u> cal/cm/°C,              (c)</p> <p style="text-align: center;"><u>°C</u></p> <p>-50    0.141 0    0.158 25    0.164 50    0.167</p>	

Preparation:

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

Sensitivity to Static Discharge, joules: (b) 0.0009

Loss in Weight at 105°C: %

3 hours	0.02
6 hours	0.23
9 hours	0.23

Effect of Storage for 2 Months at 80°C, on:

Explosion Temperature Test Value	Ni 1
Sand Test Value	Ni 1
Sensitivity to Initiation	Ni 1

Solubility, gm/100 gm (%) in:

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

Origin:

First described in 1914 by von Hertz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw &, 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 sty-phnate is decomposed by dissolving it in at least 40 times its weight of 20% sodium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References: <sup>41</sup>

- (a) Report AC-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, PAIR No. 2224, November 1955.
- (d) Also see the following Picatinny Arsenal Technical Reports on Lead Sty-phnate:

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

---

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

Composition: % C 15.9 H 1.8 N 18.6 O 63.8 C/H Ratio 0.133		Molecular Weight: (C <sub>6</sub> H <sub>8</sub> N <sub>6</sub> O <sub>18</sub> )	452
		Oxygen Balance: CO, % CO <sub>2</sub> %	7.1 28.3
		Density: gm/cc	1.73
		Melting Point: °C	112-113
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	11 4 11	Boiling Point: °C	Decomposes 150
		Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Detonates Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions Partial Burned Unaffected	%	200 Gram Bomb Sand Test: Sand, gm	68.5
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	160-170 (a) 232 (b) 175 (c)	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	-- 0.06 --
		Ballistic Mortar, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs	0.4	Trauzl Test, % TNT: (c)	172
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs (Frothed)	-- -- 48 hours	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:		Detonation Rate: (d)	Yes Pressed
Hygroscopicity: % 30°C, 90% RH	0.17	Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	0.5 1.73 8260
Volatility:			

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b></p> <p><b>Principal Uses:</b> Secondary charge in detonators (ref i), and in blasting caps designed to be initiated by a fuse (ref j)</p> <p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth				
	Glass Cones	Steel Cones										
Hole Volume												
Hole Depth												
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: center;">Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: center;">Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td style="text-align: center;">None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation	None			
Method	Dry											
Hazard Class (Quantity-Distance)	Class 9											
Compatibility Group												
Exudation	None											
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><u>65.5°C KI Test:</u></p> <table border="0"> <tr> <td>Minutes</td> <td style="text-align: center;">6</td> </tr> </table> <p><u>Heat of:</u> (e, f, g)</p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>1515</td> <td>1525</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1390 1454</td> <td>1468 1520</td> </tr> <tr> <td>Formation, cal/gm</td> <td>337 345</td> <td>366</td> </tr> </table>	Minutes	6	Combustion, cal/gm	1515	1525	Explosion, cal/gm	1390 1454	1468 1520	Formation, cal/gm	337 345	366
Minutes	6											
Combustion, cal/gm	1515	1525										
Explosion, cal/gm	1390 1454	1468 1520										
Formation, cal/gm	337 345	366										

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, Sarrau and Vieille, Domonte, Menard, Strecker, Tichanowich (Ph. Naoum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Explosives," Industria Chimica 8, 1093-1102 (1933)).

References:<sup>42</sup>

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

<sup>42</sup>See footnote 1, page 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. Naum, 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 **111**, London (1932) p. 39. Ph. Naum, Nitroglycerin and Nitroglycerin Explosives, Baltimore, (1928), pp. 156, 247-250.
- (g) A. Schmidt, *Z ges Schiess - Sprengstoffw* 29, 262 (1934) G. Fleury, L. Brissand and P. Lhoste, "Structure and Stability of Nitric Esters," *Comp rend* 224, 1016-18 (1947).  
W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PAIR No. 1651, 22 April 1947.
- (h) Sarran and Vielle, *Mém poudr* 2, 161 (1884-1889).
- (i) E. von Hertz, 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-TML-16, 23 January 1952.
- (m) Also see the following Picatinny Arsenal Technical Reports on Mannitol Hexanitrate:

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



Composition: % C 8.4 N 9.8 O 11.2 Hg 70.6 C/H Ratio		Molecular Weight: (HgC <sub>2</sub> N <sub>2</sub> O <sub>2</sub> )	285
		Oxygen Balance: CO, % CO %	-17 -5.5
		Density: gm/cc Crystal	4.43
		Melting Point: °C	Decomposes
		Freezing Point: °C	
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	Boiling Point: °C		
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>		
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe Explodes	Vacuum Stability Test: cc/40 Hrs, at 90 °C 100 °C Explodes 120 °C 135 °C 150 °C		
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand gm Black powder fuse 21.4		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 263 1 239 5 Explodes 210 10 199 15 194 20 190	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
75°C International Heat Test: % Loss in 48 Hrs 0.18	Ballistic Mortar, % TNT: Trauzl Test, % TNT: (a) 51		
100°C Heat Test: Exploded in 16 hours % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
Flammability Index:	Detonation Rate: Confinement Condition Pressed Charge Diameter, in. Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 3500 4250 5000		
Hygroscopicity: % 30°C, 90% RH 0.02			
Volatility:			

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																	
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	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M (wet)</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M (wet)	Exudation	None																
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	<p><b>Stab Sensitivity:</b></p> <table> <tr> <td>Density</td> <td colspan="3">Firing Point (inch-ounces)</td> </tr> <tr> <td><u>gm/cc</u></td> <td><u>0%</u></td> <td><u>50%</u></td> <td><u>100%</u></td> </tr> <tr> <td>3.91</td> <td>3.2</td> <td>4.3</td> <td>5.5</td> </tr> <tr> <td>4.26</td> <td>1.6</td> <td>2.6</td> <td>5.5</td> </tr> <tr> <td>4.32</td> <td>1.6</td> <td>2.6</td> <td>4.0</td> </tr> <tr> <td>4.50</td> <td>1.6</td> <td>2.5</td> <td>4.0</td> </tr> </table>	Density	Firing Point (inch-ounces)			<u>gm/cc</u>	<u>0%</u>	<u>50%</u>	<u>100%</u>	3.91	3.2	4.3	5.5	4.26	1.6	2.6	5.5	4.32	1.6	2.6	4.0	4.50	1.6	2.5	4.0
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<p><b>Activation Energy:</b></p> <table> <tr> <td>kcal/mol</td> <td>29.81</td> </tr> <tr> <td>Induction Period, sec</td> <td>0.5-10</td> </tr> </table>	kcal/mol	29.81	Induction Period, sec	0.5-10																					
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<p><b>Thermal Conductivity:</b></p> <table> <tr> <td>cal/sec/cm/°C</td> <td>1 x 10<sup>-4</sup></td> </tr> </table>	cal/sec/cm/°C	1 x 10 <sup>-4</sup>																							
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Initiating Efficiency; Grams Required to Give Complete Initiation of:

	<u>Fulminate, gm</u>
TNT	0.25
Tetryl	0.20
RDX	0.19
PEIN	0.17

Compatibility with Metals:

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

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

Sensitivity to Static Discharge, Joules: (b) 0.025

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

<u>Months Storage</u>	<u>Recrystallized Lots</u>				<u>Uncrystallized Lots</u>	
	<u>979</u>	<u>980</u>	<u>981</u>	<u>982</u>	<u>505.6-7/31</u>	<u>505.3-5/11</u>
0	99.75	99.77	99.79	99.79	98.86	
4						98.7
6	99.38	99.45	99.54	99.47	95.95	98.7
8						97.4
9					94.95	
10						94.9
12	98.74	99.56	97.49	99.06	90.65	
13	98.26			98.79		
14	98.22					
15	97.52	99.30	99.30	98.19	83.76	
16	97.00		99.01	97.75		
17	95.70	98.66		96.69		
18	94.81	98.58	98.46	95.90	79.99	
23					74.52	
26					63.80	

Chemistry:

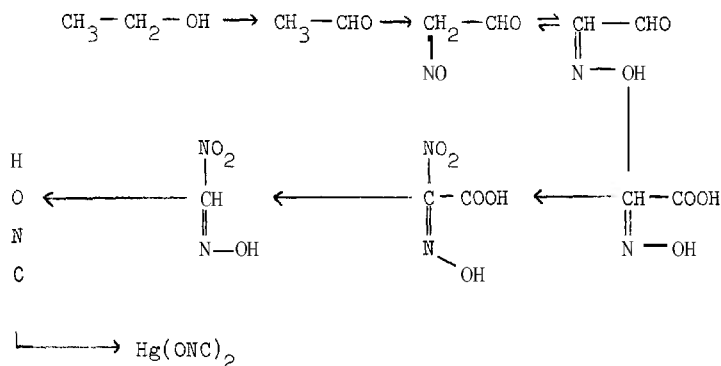
Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing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

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

<u>°C</u>	<u>%</u>
12	0.07
49	0.18

Preparation:

(Chemistry of Powder and Explosives, Davis)



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

Origin:

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

Destruction by Chemical Decomposition:

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

References: <sup>43</sup>

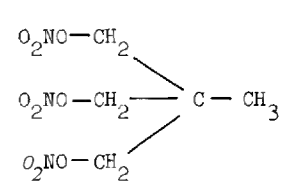
- (a) Ph. Naoum - Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

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

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
250	301	132	23	144	65	266	277	28	199
480	381	452	203	294	105	366	297	78	609
510	561	522	393	534	255	556	407	278	749
550	1651	582	433	624	285	566	537	318	849
610		782	833	694	365	866	567	788	999
680		882	1183	784	415	986	637	1838	1079
760		932	1393	874	425	1316	857		1389
1220		1192	2093	1104	1325	1486	1737		2179
1450		1352			1365	1556			
		1372				2146			
		1722							
		2032							

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

Composition: % C 23.5 H 3.5 N 16.6 O 56.4 C/H Ratio 0.150		Molecular Weight: (C <sub>7</sub> H <sub>9</sub> N <sub>3</sub> O <sub>6</sub> ) 255
		Oxygen Balance: CO, % -35 CO % -3
		Density: gm/cc Liquid 1.47
		Melting Point: °C -3
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 47; (11b wt) 4 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 20 Sample Wt, mg		Boiling Point: °C
		Refractive Index, n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> 1.4752 n <sub>D</sub> <sup>30</sup>
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C cc/gm 1.9 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Particles Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 43.7
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 235 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
		Ballistic Mortar, % TNT: (a) 136
		Trauzl Test, % TNT: (b) 140
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 2.5 % Loss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.07		
Volatility: 60°C, mg/cm <sup>2</sup> /hr 24		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> Oily, slightly turbid</p> <p><b>Principal Uses:</b> Ingredient of rocket and double base propellants</p> <p><b>Method of Loading:</b></p> <p><b>Loading Density:</b> gm/cc</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth			
	Glass Cones	Steel Cones									
Hole Volume											
Hole Depth											
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Liquid</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td></td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Liquid	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation			
Method	Liquid										
Hazard Class (Quantity-Distance)											
Compatibility Group											
Exudation											
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Solubility in Water, gm/100 gm, at:</b></p> <table border="0"> <tr> <td>25°C</td> <td>&lt; 0.015</td> </tr> <tr> <td>60°C</td> <td>&lt; 0.015</td> </tr> </table> <p><b>Heat of:</b></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2642</td> </tr> </table> <p><b>Hydrolysis, % Acid:</b></p> <table border="0"> <tr> <td>10 days at 22°C</td> <td>0.018</td> </tr> <tr> <td>5 days at 60°C</td> <td>0.115</td> </tr> </table>	25°C	< 0.015	60°C	< 0.015	Combustion, cal/gm	2642	10 days at 22°C	0.018	5 days at 60°C	0.115
25°C	< 0.015										
60°C	< 0.015										
Combustion, cal/gm	2642										
10 days at 22°C	0.018										
5 days at 60°C	0.115										

Preparation:

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

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 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<sub>3</sub>/H<sub>2</sub>SO<sub>4</sub> maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with a sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

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

References: 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.

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



Composition: %		Molecular Weight:	77
Ammonium Nitrate	40	Oxygen Balance:	
TNT	40	CO <sub>2</sub> %	-38
Aluminum	20	CO %	-20
C/H Ratio		Density: gm/cc	1.62-1.68
		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	35	Refractive Index, n <sub>20</sub> <sup>D</sup>	
Sample Wt 20 mg		n <sub>25</sub> <sup>D</sup>	
Picatunny Arsenal Apparatus, in.	13	n <sub>30</sub> <sup>D</sup>	
Sample Wt, mg	17		
Friction Pendulum Test:		Vacuum Stability test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
		100°C	
Rifle Bullet Impact test: Trials		120°C	2.1
Explosions %		135°C	
Partials		150°C	
Burned		200 Gram Bomb Sand test:	
Unaffected		Sand, gm	
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5 Ignites	435	Lead Azide	
10		Tetryl	
15		Ballistic Mortar, % TNT: (a)	143
20		Traurl Test, % TNT: (b)	165
75°C International Heat Test:		Plate Dent test: (c)	
% Loss in 48 Hrs		Method	B
100°C Heat test:		Condition	Pressed
% Loss, 1st 48 Hrs		Confined	No
% Loss, 2nd 48 Hrs		Density, gm/cc	1.73
Explosion in 100 Hrs		Brisance, % TNT	66
Flammability Index:	100	Detonation Rate: (d)	
Hygroscopicity: %		Confinement	None
Volatility:		Condition	Cast
		Charge Diameter, in.	1.6
		Density, gm/cc	1.68
		Rate, meters/second	5820

<p><b>Booster Sensitivity Test:</b> (e)                  Condition Pressed                  Tetryl, gm 100                  Wax, in. for 50% Detonation 1.46                  Wax, gm                  Density, gm/cc 1.74</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec (Z/sec)                  Heat, kilocalorie/mole (<math>\Delta H</math>, kcal/mol)                  Temperature Range, °C                  Phase</p>
<p><b>Heat of:</b> (f)                  Combustion, cal/gm 3160                  Explosion, cal/gm 1620                  Gas Volume, cc/gm                  Formation, cal/gm                  Fusion, cal/gm</p>	<p><b>Armor Plate Impact Test:</b> (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</p>
<p><b>Specific Heat:</b> cal/gm/°C                  At -5°C 0.30                  Density, gm/cc 1.74</p>	
<p><b>Burning Rate:</b>                  cm/sec</p>	
<p><b>Thermal Conductivity:</b> (b)                  col/sec/cm/°C <math>16.5 \times 10^{-4}</math>                  Density, gm/cc 1.74</p>	
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                   Volume, %/°C</p>	<p><b>Bomb Drop Test:</b>                   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</p>
<p><b>Hardness, Mohs' Scale:</b></p>	
<p><b>Young's Modulus:</b> (b)                  E, dynes/cm<sup>2</sup> <math>5.03 \times 10^{10}</math>                  E, lb/inch<sup>2</sup> <math>0.73 \times 10^6</math>                  Density, gm/cc 1.66</p>	
<p><b>Compressive Strength:</b> lb/inch<sup>2</sup> (b) 1910-2070                  Density, gm/cc 1.68</p>	
<p><b>Vapor Pressure:</b>                  °C mm Mercury</p>	

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

Origin:

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

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

References: 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. NCL 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.

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

Composition:		Molecular Weight:	40.6
%		Oxygen Balance:	
Oxidizing agent (Ammonium Perchlorate)	35.0	CO, %	-44
Aluminum, atomized	26.2	CO %	-37
Cupric Oxide	----		
Magnesium, atomized	26.2	Density: gm/cc	Pressed 2.0
Other ingredient (Tetryl)	9.7		
Calcium Stearate	1.9	Melting Point: °C	
Graphite, artificial	1.0		
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	--		
Sample Wt 20 mg		Refractive Index, $n_{20}^D$	
Picatinny Arsenal Apparatus, in.	13	$n_{25}^D$	
Sample Wt, mg	22	$n_{50}^D$	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Detonates	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
		100°C	0.47
Rifle Bullet Impact Test: Trials		120°C	
	%	135°C	
Explosions		150°C	
Partials			
Burned		200 Gram Bomb Sand Test:	
Unaffected		Sand, gm	10.6
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5	285	Lead Azide	0.20
10		Tetryl	0.25
15			
20		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		Method	
Discoloration, fumes, odor	None	Condition	
100°C Heat Test:		Confined	
% Loss, 1st 48 Hrs	0.10	Density, gm/cc	
% Loss, 2nd 48 Hrs	0.01	Brisance, % TNT	
Explosion in 100 Hrs	None		
Flammability Index:		Detonation Rate:	
		Confinement	
Hygroscopicity: %		Condition	
		Charge Diameter, in.	
Volatility:		Density, gm/cc	
		Rate, meters/second	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume                  Hole Depth</p> <hr/> <p><b>Color:</b>      Gray powder mixture</p> <hr/> <p><b>Principal Uses:</b>      Small caliber antiaircraft projectiles</p> <hr/> <p><b>Method of Loading:</b>      Pressed</p> <hr/> <p><b>Loading Density: gm/cc</b>                  At 30,000 psi      ~ 2.0</p> <hr/> <p><b>Storage:</b></p> <p>Method      Dry</p> <p>Hazard Class (Quantity-Distance)      Class 9</p> <p>Compatibility Group      Group I                  Bureau of Explosives Classification Class A</p> <p>Exudation</p> <hr/> <p><b>Heat of:</b></p> <p>Combustion, cal/gm      4087                  Explosion, cal/gm      2087                  Gas volume, cc/gm      212</p> <hr/> <p><b>Performance Tests:</b>  <u>20 mm T215E1 Projectile:</u></p> <p>NFOC Pressure Cube      35                  APG Blast Cube      40</p> <hr/> <p><b>Activation Energy:</b></p> <p>kcal/mol      12.5                  Temp, °C      300 to 330                  Time to ignition, seconds      <math>1.78 \times 10^{-4}</math></p>
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	

Coyorition:		Molecular Weight:	42
Oxidizing agent (Ammonium Perchlorate)	35.0	Oxygen Balance:	
Aluminum, atomized	52.4	CO, %	-49
Cupric Oxide	----	CO %	-43
Magnesium, atomized	----	Density: gm/cc	Pressed 2.0
Other ingredients*	9.7	Melting Point: °C	
Calcium Stearate	1.9	Freezing Point: °C	
Graphite, artificial	1.0		
*5.8% RDX and 3.9% TNT coated on Ammonium Perchlorate.			
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.	12	$n_{30}^D$	
Sample Wt, mg	24		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
		100°C	0.21
		120°C	
		135°C	
		150°C	
Rifle Bullet Impact Test:	Trials	200 Gram Bomb Sand Test:	
	%	Sand, gm	11.5
Explosions			
Partials			
Burned			
Unaffected			
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5	375	Lead Azide	0.20
10		Tetryl	0.20
15			
20		Ballistic Mortar, % TNT:	
		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs		Method	
Discoloration, fumes, odor	None	Condition	
		Confined	
100°C Heat Test:		Density, gm/cc	
% Loss, 1st 48 Hrs	0.27	Brisance, % TNT	
% Loss, 2nd 48 Hrs	0.12		
Explosion in 100 Hrs	None		
Flammability Index:		Detonation Rate:	
		Confinement	
		Condition	
Hygroscopicity: %		Charge Diameter, in.	
		Density, gm/cc	
Volatility:		Rate, meters/second	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones     Steel Cones</p> <p>Hole Volume                  Hole Depth</p>																											
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Gray</p>																											
<p><b>Blast (Relative to TNT):</b></p> <table border="0" style="width: 100%;"> <tr> <td><b>Air: Bare Charge:</b></td> <td style="text-align: center;"><u>EW*</u></td> <td style="text-align: center;"><u>EV*</u></td> </tr> <tr> <td>Peak Pressure</td> <td style="text-align: center;">1.02</td> <td style="text-align: center;">1.34</td> </tr> <tr> <td>Impulse</td> <td style="text-align: center;">1.08</td> <td style="text-align: center;">1.41</td> </tr> <tr> <td>Energy</td> <td></td> <td></td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td style="text-align: center;">1.96</td> </tr> </table> <p><b>Air, Confined:</b>                  Impulse</p> <p><u>Cased Charge in Air:**</u></p> <table border="0" style="width: 100%;"> <tr> <td>Peak Pressure</td> <td style="text-align: center;">1.09</td> <td style="text-align: center;">1.44</td> </tr> <tr> <td>Impulse</td> <td style="text-align: center;">1.16</td> <td style="text-align: center;">1.53</td> </tr> <tr> <td>Energy</td> <td style="text-align: center;">----</td> <td style="text-align: center;">----</td> </tr> <tr> <td>Density, gm/cc</td> <td></td> <td style="text-align: center;">1.98</td> </tr> </table> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p> <p>*EW, equivalent weight as compared to TNT.                  EV, equivalent volume as compared to TNT.</p> <p>**Strong paper-base phenolic case.</p>	<b>Air: Bare Charge:</b>	<u>EW*</u>	<u>EV*</u>	Peak Pressure	1.02	1.34	Impulse	1.08	1.41	Energy			Density, gm/cc		1.96	Peak Pressure	1.09	1.44	Impulse	1.16	1.53	Energy	----	----	Density, gm/cc		1.98	<p><b>Principal Uses:</b> HE filler for small caliber projectiles</p>
<b>Air: Bare Charge:</b>	<u>EW*</u>	<u>EV*</u>																										
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Effect of Altitude, Charge Diameter and Degree of Confinement on Detonation Velocity\*  
(Reference g)

Ground		4730	
30,000	Charge would not	4530(3)	Charge would

\*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	Ground	30,000	60,000	90,000
		m/s	m/s	m/s	m/s
MOX-2B,	1	2012	**	**	**
density 207 gm/cc	2	3314	3351	3247	**

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

\*\*Charge would not propagate detonation.

Composition:		Molecular Weight:	45.6
Oxidizing agent (Potassium Nitrate)	18	Oxygen Balance:	
Aluminum, atomized	50	CO, %	-52
Cupric Oxide	--	CO %	-43
Magnesium, atomized	--	Density: gm/cc	Pressed 2.0
Other ingredients*	32	Melting Point: °C	
Calcium Stearate**	2.0	Freezing Point: °C	
Graphite, artificial**	1.0	Boiling Point: °C	
*29.1% RDX, 0.9% wax, and 2.0% TNT.		Refractive Index, $n_{20}^D$	
**Per cent added.		$n_{25}^D$	
Impact Sensitivity, 2 Kg Wt:		$n_{30}^D$	
Bureau of Mines Apparatus, cm	--	Vacuum Stability Test:	
Sample Wt 20 mg		cc/40 Hrs, at	
Picatinny Arsenal Apparatus, in.	17	90°C	----
Sample Wt, mg	24	100°C	0.57
Friction Pendulum Test:		120°C	
Steel Shoe	Unaffected	135°C	
Fiber Shoe	Unaffected	150°C	
Rifle Bullet Impact Test:	Trials	200 Gram Bomb Sand Test:	
	%	Sand, gm	33.2
Explosions		Sensitivity to Initiation:	
Partials		Minimum Detonating Charge, gm	
Burned		Mercury Fulminate	----
Unaffected		Lead Azide	0.20
Explosion Temperature: °C		Tetryl	0.15
Seconds, 0.1 (no cap used)	---	Ballistic Mortar, % TNT:	
1	---	Trauzl Test, % TNT:	
5	540	Plate Dent Test:	
10		Method	
15		Condition	
20		Confined	
75°C International Heat Test:		Density, gm/cc	
% Loss in 48 Hrs		Brisance, % TNT	
Discoloration, fumes, odor	None	Detonation Rate:	
100°C Heat Test:		Confinement	
% Loss, 1st 48 Hrs	0.35	Condition	
% Loss, 2nd 48 Hrs	0.13	Charge Diameter, in.	
Explosion in 100 Hrs	None	Density, gm/cc	
Flammability Index:		Rate, meters/second	
Hygroscopicity: %			
Volatility:			

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth															
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc                  At 30,000 psi ~ 2.0</p> <p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td></td> <td>Bureau of Explosives Class A</td> </tr> </table> <p><b>Heat of:</b></p> <table> <tr> <td>Combustion, cal/gm</td> <td>4331</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>980</td> </tr> <tr> <td>Gas volume, cc/gm</td> <td>232</td> </tr> </table> <p><b>Performance Tests:</b>  <u>20 mm T215E1 Projectile:</u></p> <table> <tr> <td>NFOC Pressure Cube</td> <td>37</td> </tr> <tr> <td>ARG Blast Cube</td> <td>52</td> </tr> </table> <p><b>Activation Energy:</b></p> <table> <tr> <td>kcal/mol</td> <td rowspan="3">Values not included due to erratic ignition under conditions of test.</td> </tr> <tr> <td>Temp. °C</td> </tr> <tr> <td>Time to ignition, seconds</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I		Bureau of Explosives Class A	Combustion, cal/gm	4331	Explosion, cal/gm	980	Gas volume, cc/gm	232	NFOC Pressure Cube	37	ARG Blast Cube	52	kcal/mol	Values not included due to erratic ignition under conditions of test.	Temp. °C	Time to ignition, seconds
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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.	Molecular Weight: 48
	Oxygen Balance: CO, % -53 CO % -43
	Density: gm/cc Pressed 2.0
	Melting Point: °C
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 26	Boiling Point: °C
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$
Friction Pendulum Test: Steel Shoe Sparks Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ---- 100°C 0.67 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 33.6
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 610 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.20 Tetryl 0.15
	Ballistic Mortar, % TNT:
	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 0.22 % Loss, 2nd 48 Hrs 0.12 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Flammability Index:	
Hygroscopicity: %	
Volatility:	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> Gray powder mixture</p> <p><b>Principal Uses:</b> Small caliber antiaircraft projectiles</p> <p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc At 30,000 psi ~ 2.0</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth							
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Heat of:</b></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>4392</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>709</td> </tr> <tr> <td>Gas volume, cc/gm</td> <td>208</td> </tr> </table> <p><b>Performance Tests:</b> <u>20 mm T215E1 Projectile:</u></p> <table border="0"> <tr> <td>NFOC Pressure Cube</td> <td>43</td> </tr> <tr> <td>APG Blast Cube</td> <td>53</td> </tr> </table> <p><b>Aviation Energy:</b></p> <table border="0"> <tr> <td>kcal/mol</td> <td rowspan="4">Values not included due to erratic igni- tion under conditions of test.</td> </tr> <tr> <td>Temp, °C</td> </tr> <tr> <td>Time to ignition, seconds</td> </tr> </table>	Combustion, cal/gm	4392	Explosion, cal/gm	709	Gas volume, cc/gm	208	NFOC Pressure Cube	43	APG Blast Cube	53	kcal/mol	Values not included due to erratic igni- tion under conditions of test.	Temp, °C	Time to ignition, seconds
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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	Molecular Weight: 43
	Oxygen Balance: CO <sub>2</sub> % -50 CO % -42
	Density: gm/cc
	Melting Point: °C
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 78 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27	Boiling Point: °C
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ----- 100°C 0.43 120°C 135°C 150°C
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 10.8
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 510 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ----- Lead Azide 0.20 Tetryl 0.16
	Ballistic Mortar, % TNT:
	Trauzl Test, % TNT:
75°C International Heat Test: % Loss in 48 Hrs Discoloration, fumes, odor 0.02/10 gm None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
100°C Heat Test: % Loss, 1st 48 Hrs 0.00 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
Flammability Index:	
Hygroscopicity: % 30°C, 90% RH, two weeks 0.79	
Volatility:	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth			
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keca 1/mo 1	Values not included due to erratic ignition under conditions of test.										
Temp. °C											
Time to ignition, seconds											

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:<sup>46</sup>

(a) A. O. Mirarchi and A. T. Wilson, Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract NOrd-10975, Task I, 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.

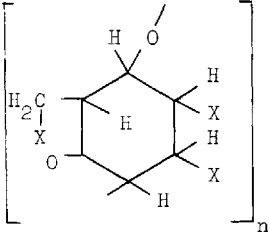
(g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

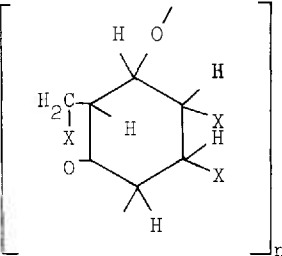
(h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3755, 5 April 1956.

(i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204, 2205.

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<sup>46</sup>See footnote 1, page 10.

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

<b>Composition :</b> % C 25.29 H 2.52 N 13.45 O 58.74 X=ONO <sub>2</sub>  C/H Ratio 0.23		Molecular Weight: (286.34) <sub>n</sub>
		Oxygen Balance: CO <sub>2</sub> % -29 CO % 4.7
		Density: gm/cc
		Melting Point: °C Decomposes
		Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 9 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 0.42 100°C 1.5 120°C 11.+ 135°C 150°C	
Rifle Bullet Impact Test:      Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 49.0	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 230 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.10 Tetryl	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: 125 Traust Test, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs 0.3 % Loss, 2nd 48 Hrs 0.0 Explosion in 100 Hrs None	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Flammability Index:	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc 1.20 Rate, meters/second 7300	
Hygroscopicity: % 30°C, 90% RH ~ 2		
Volatility: 60°C, mg/cm <sup>2</sup> /hr 0.0		

<p>Composition:</p> <p>%</p> <p>C 24.25</p> <p>H 2.37</p> <p>N 14.14</p> <p>O 59.24</p> <p>X=ONO<sub>2</sub></p> <p>C/H Ratio 0.23</p>		Molecular Weight:	(297.15) <sub>n</sub>
		Oxygen Balance:	
		CO, %	-24
		CO %	8
		Density: gm/cc	1.65-1.70
Melting Point: °C	Decomposes		
Freezing Point: °C			
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	8	Refractive Index, n <sub>20</sub> <sup>D</sup>	
Sample Wt 20 mg		n <sub>25</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in.	3	n <sub>30</sub> <sup>D</sup>	
Sample Wt, mg	5		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	1.46
Rifle Bullet Impact Test:	Trials	100°C 14 hours	11.+
	%	120°C 16 hours	11.+
Explosions		135°C	
Partials		150°C	
Burned		200 Grom Bomb Sand Test:	
Unaffected		Sand, gm	52.3
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	
5		Lead Azide	0.10
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: % 30°C, 90% RH	~ 1	Confinement	
Volatility: 60°C, mg/cm <sup>2</sup> /hr	0.0	Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth									
	Glass Cones	Steel Cones															
Hole Volume																	
Hole Depth																	
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Color:</b> White</p>																
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Principal Uses:</b> Pyroxylin (12%N), blasting explosives; pyrocellulose (12.60% N), smokeless powder; guncotton (13.35% N minimum), propellants</p>																
	<p><b>Method of Loading:</b></p>																
	<p><b>Loading Density:</b> gm/cc</p>																
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Wet (8% to 30% water)</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 12</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M (wet)</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet (8% to 30% water)	Hazard Class (Quantity-Distance)	Class 12	Compatibility Group	Group M (wet)	Exudation	None								
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Exudation	None																
	<p><b>Heat of:</b></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>2409*</td> <td>2313**</td> <td>2228***</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>855*</td> <td>965**</td> <td>1058***</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>919*</td> <td>883**</td> <td>853***</td> </tr> <tr> <td>Formation, cal/gm</td> <td>617*</td> <td>561**</td> <td>513***</td> </tr> </table> <p>* 12.6% N ** 13.45% N *** 14.14% N</p>	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***
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	<p><b>Vapor Pressure:</b></p> <table border="0"> <tr> <td><u>°C</u></td> <td><u>mm Mercury</u></td> </tr> <tr> <td>25</td> <td>0.00</td> </tr> <tr> <td>60</td> <td>0.00</td> </tr> </table>	<u>°C</u>	<u>mm Mercury</u>	25	0.00	60	0.00										
<u>°C</u>	<u>mm Mercury</u>																
25	0.00																
60	0.00																

Nitrocellulose (NC)

<u>Solubility in Water, gm/100 gm. at:</u>	<u>12.6% N</u>	<u>13.45% N</u>	<u>14.0% N</u>
25°C	Insoluble	Insoluble	Insoluble
60°C	Insoluble	Insoluble	Insoluble
<u>Solubility, gm/100 gm, 25°C, in:</u>			
Ether	Insoluble	Insoluble	Insoluble
Alcohol	Very slightly soluble	Practically insoluble	Insoluble
2:1-Ether:Alcohol	Soluble	Slightly soluble (6%-11%)	Practically insoluble (1 + %)
Acetone	Soluble	Soluble	Soluble
<u>240-Hour Hydrolysis Test,</u> <u>% Nitric Acid</u>	1.22	1.03	

Preparation of Nitrocellulose from Cotton Linters:  
(Laboratory Procedure)

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

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

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

Temperature of acid at the start 34°C

Time of nitration 24 minutes

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

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

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

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.

Orinin:

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 colloidized, 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:<sup>47</sup>

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

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

Nitrocellulose (NC)

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
10	41	72	13	4	125	86	167	8	19
390	101	332	33	24	475	576	327	198	29
420	231	402	43	114	485	586	407	208	69
660	351	422	133	174	495	796	717	278	169
730	551	542	233	194	555	916	787	388	279
960	831	572	253	334	705	1016	987	408	499
1020	851	652	273	374	965	1026	1187	588	659
1100	971	662	653	394	1065	1066	1197	718	669
1150	1031	752	673	724	1125	1206	1267	758	709
1190	1041	802	683	804	1135	1256	1297	778	739
1210	1071	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								



<b>Composition:</b> % C 15.9 H 2.2 N 18.5 O 63.4 C/H Ratio 0.109	$  \begin{array}{c}  \text{H}_2\text{C} \quad \text{ONO}_2 \\    \\  \text{HC} \quad \text{ONO}_2 \\    \\  \text{H}_2\text{C} \quad \text{ONO}_2  \end{array}  $		Molecular Weight: (C H N O) 227
	Oxygen Balance: CO <sub>2</sub> % 3.5 CO % 24.5		
	Density: gm/cc 25°C, Liquid 1.591 20°C, Liquid 1.596		
	Melting Point: °C Labile form 2.2 Stable form 13.2		
	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 1 lb wt 1 Sample Wt, mg	Boiling Point: °C Decomposes 145		
	Refractive Index, n <sub>20</sub> <sup>D</sup> 1.4732 n <sub>25</sub> <sup>D</sup> 1.4713 n <sub>30</sub> <sup>D</sup>		
Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C cc/gm/6 hrs 1.6 100°C cc/gm/16 hrs 11+ 120°C 135°C 150°C		
Rifle Bullet Impact Test: Trials Explosions 100 Partial 0 Burned 0 Unaffected 0	200 Gram Bomb Sand Test: Sand, gm Liquid method 51.5		
	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 222 10 15 20	Ballistic Mortar, % TNT: (a) 140 Trauzl Test, % TNT: (b) 181		
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT		
100°C Heat Test: % Loss, 1st 48 Hrs 3.6 % Loss, 2nd 48 Hrs 3.5 Explosion in 100 Hrs None	Detonation Rate: Confinement Glass Steel Condition Liquid Liquid Charge Diameter, in. 0.39 1.25 Density, gm/cc 1.6 1.6 Rate, meters/second 1600-1900 7700		
Flammability Index:			
Hygroscopicity: % 30°C, 90% RH 0.06			
Volatility: 60°C, mg/cm <sup>2</sup> /hr 0.11			

<p><b>Booster Sensitivity Test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Decomposition Equation:</b></p> <table border="0"> <tr> <td>Oxygen, atoms/sec (Z/sec)</td> <td>10<sup>17.3</sup></td> <td>10<sup>19.2</sup></td> </tr> <tr> <td>Heat, kilocalorie/mole (AH, kcal/mol)</td> <td>41.4</td> <td>45.0</td> </tr> <tr> <td>Temperature Range, °C</td> <td>90-135</td> <td>125-150</td> </tr> <tr> <td>Phase</td> <td>Liquid</td> <td>Liquid</td> </tr> </table>	Oxygen, atoms/sec (Z/sec)	10 <sup>17.3</sup>	10 <sup>19.2</sup>	Heat, kilocalorie/mole (AH, kcal/mol)	41.4	45.0	Temperature Range, °C	90-135	125-150	Phase	Liquid	Liquid								
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<p><b>Heat of:</b>                  Combustion, cal/gm 1616                  Explosion, cal/gm 1600                      Gas Volume, cc/gm 715                  Formation, cal/gm 400                  Fusion, cal/gm                  Detonation, cal/gm 1486</p>	<p><b>Armor Plate Impact Test:</b></p> <p><b>60 mm Mortar Projectile:</b>                  50% Inert, Velocity, ft/sec                  Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b></p> <p>Plate Thickness, inches</p> <p>1                  1¼                  1½                  1¾</p>																				
<p><b>Specific Heat: cal/gm/°C</b></p> <p>Liquid 0.356                  Solid 0.315</p>	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p> <p>Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p> <p><b>1000-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p>																				
<p><b>Burning Rate:</b>                  cm/sec</p>																					
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C</p>																					
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                  Volume, %/°C</p>																					
<p><b>Hardness, Mohs' Scale:</b></p>																					
<p><b>Young's Modulus:</b>                  E, dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>																					
<p><b>Compressive Strength: lb/inch<sup>2</sup></b></p>																					
<p><b>Vapor Pressure:</b></p> <table border="0"> <thead> <tr> <th>°C</th> <th>mm Mercury</th> <th>°C</th> <th>mm Mercury</th> </tr> </thead> <tbody> <tr> <td>20</td> <td>0.00025</td> <td>60</td> <td>0.0188</td> </tr> <tr> <td>30</td> <td>0.00083</td> <td>70</td> <td>0.043</td> </tr> <tr> <td>40</td> <td>0.0024</td> <td>80</td> <td>3.098</td> </tr> <tr> <td>50</td> <td>0.0073</td> <td>90</td> <td>0.23</td> </tr> </tbody> </table>	°C	mm Mercury	°C	mm Mercury	20	0.00025	60	0.0188	30	0.00083	70	0.043	40	0.0024	80	3.098	50	0.0073	90	0.23	
°C	mm Mercury	°C	mm Mercury																		
20	0.00025	60	0.0188																		
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40	0.0024	80	3.098																		
50	0.0073	90	0.23																		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume                  Hole Depth</p> <hr/> <p><b>Color:</b> <span style="float: right;">Colorless</span></p> <hr/> <p><b>Principal Uses:</b> Propellant ingredient, demolition explosive ingredient, grenade burster ingredient</p> <hr/> <p><b>Method of Loading:</b></p> <hr/> <p><b>Loading Density:</b> gm/cc</p>												
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method With acetone or other desensitizer, generally not stored</p> <p>Hazard Class (Quantity-Distance) <span style="float: right;">Class 9</span></p> <p>Compatibility Group</p> <p>Exudation</p>												
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Heat of Transition, cal/gm:</b></p> <p style="text-align: center;"><u>Transition:</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding-left: 20px;">Liquid → labile</td> <td style="text-align: right;">5.2</td> </tr> <tr> <td style="padding-left: 20px;">Labile → stable</td> <td style="text-align: right;">28.0</td> </tr> <tr> <td style="padding-left: 20px;">Liquid → stable</td> <td style="text-align: right;">33.2</td> </tr> </table> <p><b>Hydrolysis, % Acid:</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding-left: 20px;">10 days at 22°C</td> <td style="text-align: right;">&lt; 0.002</td> </tr> <tr> <td style="padding-left: 20px;">5 days at 60°C</td> <td style="text-align: right;">0.005</td> </tr> </table> <p><b>82.1°C KI Test:</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding-left: 20px;">Minutes</td> <td style="text-align: right;">10+</td> </tr> </table>	Liquid → labile	5.2	Labile → stable	28.0	Liquid → stable	33.2	10 days at 22°C	< 0.002	5 days at 60°C	0.005	Minutes	10+
Liquid → labile	5.2												
Labile → stable	28.0												
Liquid → stable	33.2												
10 days at 22°C	< 0.002												
5 days at 60°C	0.005												
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)

<u>°C</u>	<u>Centipoises</u>
10	69.2
20	36.0
30	21.0
40	13.6
50	9.4
60	6.8

Fragmentation Test:

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

Nitroglycerin	22
Tetranitromethane	17

Minimum Propagating Diameter: (d)

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

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

&gt; 12.5

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

<u>Water</u>		<u>Alcohol</u>		<u>Trichlorethylene</u>		<u>Carbon Tetrachloride</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
15	0.16	0	37.5	Rm	22	Rm	2
20	0.18	20	54.0				
50	0.25						

Nitroglycerin (Liquid)

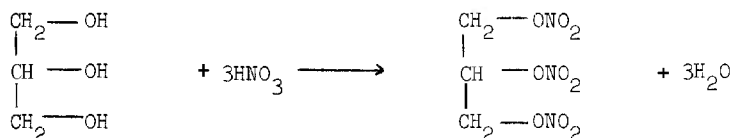
<u>Carbon Disulfide</u>		<u>gm/100 gm (%), at 25°C in</u>	
<u>°C</u>	<u>%</u>		
Ambient	1	Ether	∞
		2: 1 Ether:Alcohol	> 100
		Acetone	∞

Soluble in all Proportions in:

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

Solubility in NG, of:

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

Preparation:

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

Origin:

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

Destruction by Chemical Decomposition:

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

References: <sup>48</sup>

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

(b) Ph. Naum, 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:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
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	1674		2056			
	1221	1692	1993	1754					
	1611	1742							
	1651	1752							
	1691	1992							
	1731								
	1781								
	1851								
	1931								
	2021								
	2181								
	2201								

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

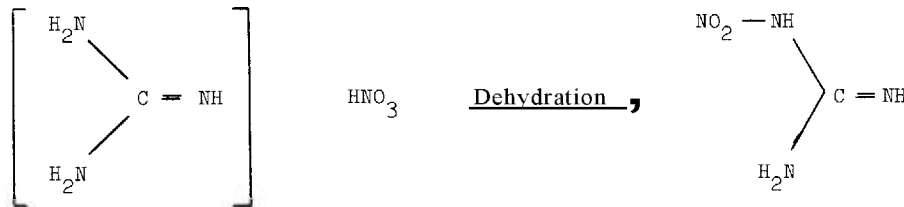
Composition: % C 11.5 H 3.9 N 53.8 O 30.8 C/H Ratio 0.038	$\text{HN}=\text{C}\begin{matrix} \text{NH}_2 \\   \\ \text{NH} \\   \\ \text{NO}_2 \end{matrix}$	Molecular Weight: $(\text{CH}_4\text{N}_4\text{O}_2)$ 104 Oxygen Balance: CO <sub>2</sub> % -31 CO % -15.4 Density: gm/cc Crystal 1.72 Melting Point: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

<b>Fragmentation test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE	<b>Shaped Charge Effectiveness, TNT = 100:</b>  <table style="width:100%; border:none;"> <tr> <td style="width:50%;"></td> <td style="text-align:center;">Glass Cones</td> <td style="text-align:center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>			Glass Cones	Steel Cones	Hole Volume			Hole Depth											
		Glass Cones	Steel Cones																	
Hole Volume																				
Hole Depth																				
	<b>Color:</b> <span style="float:right">Colorless</span>																			
	<b>Principal Uses:</b> Propellant composition ingredient, bursting charge ingredient																			
	<b>Method of Loading:</b>																			
	<b>Loading Density: gm/cc</b> At 3000 psi <span style="float:right">0.95</span>																			
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Storage:</b>  Method <span style="float:right">Dry</span>  Hazard Class (Quantity-Distance) <span style="float:right">Class 9</span>  Compatibility Group <span style="float:right">Group I</span>  Exudation																			
	<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy																			
	<b>Solubility, gm/100 gm (%), in:</b> <table style="width:100%; border:none;"> <thead> <tr> <th></th> <th style="text-align:center"><u>0C</u></th> <th style="text-align:center"><u>%</u></th> </tr> </thead> <tbody> <tr> <td>Water</td> <td style="text-align:center">25</td> <td style="text-align:center">0.44</td> </tr> <tr> <td></td> <td style="text-align:center">100</td> <td style="text-align:center">9.0</td> </tr> <tr> <td>1.0 N Potassium Hydroxide</td> <td style="text-align:center">25</td> <td style="text-align:center">1.2</td> </tr> <tr> <td>40% Sulfuric Acid</td> <td style="text-align:center">0</td> <td style="text-align:center">3.4*</td> </tr> <tr> <td></td> <td style="text-align:center">25</td> <td style="text-align:center">8.0*</td> </tr> </tbody> </table> * gm/100 cc solution <b>Booster Sensitivity Test:</b> <span style="float:right">(d)</span> Condition <span style="float:right">Pressed</span> Teteryl, gm <span style="float:right">100</span> Wax, in. for 50% Detonation <span style="float:right">0.67</span> Density, gm/cc <span style="float:right">1.41</span> <b>Heat of:</b> Combustion, cal/gm <span style="float:right">1995</span> Explosion, cal/gm <span style="float:right">721</span> Gas Volume, cc/gm <span style="float:right">1077</span> Formation, cal/gm <span style="float:right">227</span>			<u>0C</u>	<u>%</u>	Water	25	0.44		100	9.0	1.0 N Potassium Hydroxide	25	1.2	40% Sulfuric Acid	0	3.4*		25	8.0*
	<u>0C</u>	<u>%</u>																		
Water	25	0.44																		
	100	9.0																		
1.0 N Potassium Hydroxide	25	1.2																		
40% Sulfuric Acid	0	3.4*																		
	25	8.0*																		



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

Destruction by Chemical Decomposition:

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

References:<sup>49</sup>

(a) L. C. Smith and E. G. 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, NCL 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.

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

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

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1490	1391	1282	1183	1336	907	758	1439
	2181	1392	1423		2177		1749
	2201	2142	2193				

Composition: % C 16.8 2.1 19.6 O 61.5 C/H Ratio 0.126		Molecular Weight: (C <sub>4</sub> H <sub>6</sub> N <sub>4</sub> O <sub>11</sub> )	286
		Oxygen Balance: CO <sub>2</sub> % CO %	0.0 22
		Density: gm/cc	20°C 1.64
		Melting Point: °C	
		Freezing Point: °C	-39
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	25	Boiling Point: °C	
		Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	1.4896 1.4874
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	
Rifle Bullet Impact Test: Trials Explosions % Partial Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm 0.2 gm sample absorbed by 0.2 gm of kieselguhr	28
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 185 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
75°C International Heat Test: % Loss in 48 Hrs		Ballistic Mortar, % TNT:	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Trauzl Test, % TNT:	
Flammability Index:		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
Hygroscopicity: %		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	Glass (1 mm wall) Liquid 0.39 1.64 7860
Volatility: 25°C, mg/cm <sup>2</sup> /24 hrs	0.127 x 10 <sup>-3</sup>		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Yellow oil</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Gelatinizing agent for nitrocellulose</p>									
	<p><b>Method of Loading:</b></p>									
	<p><b>Loading Density: gm/cc</b></p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: center;">Liquid</td> </tr> <tr> <td colspan="2">Hazard Class (Quantity-Distance)</td> </tr> <tr> <td colspan="2">Compatibility Group</td> </tr> <tr> <td colspan="2">Exudation</td> </tr> </table>	Method	Liquid	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation		
Method	Liquid									
Hazard Class (Quantity-Distance)										
Compatibility Group										
Exudation										
	<p><b>Solubility:</b></p> <p>Soluble in methyl and ethyl alcohols, acetone, ether, ethylenedichloride, chloroform and benzene.</p> <p>Insoluble in water, carbon disulphide, and petroleum ether.</p>									
	<p><b>Toxicity:</b></p> <p>Slight, decidedly less than nitroglycerin.</p>									
	<p><b>Gelatinizing Action:</b></p> <p>Slight on nitrocellulose.</p>									
	<p><b>82.2°C KI Test:</b></p> <table border="0"> <tr> <td>Minutes</td> <td style="text-align: center;">2</td> </tr> </table>	Minutes	2							
Minutes	2									

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:<sup>50</sup>

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

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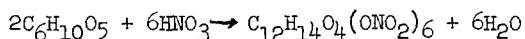
<sup>50</sup>See footnote 1, page 10.

Composition: %		Molecular Weight:	325
Nitrostarch (12.50% N)	49	Oxygen Balance:	
Barium Nitrate	40	CO, %	-19
Mononitronaphthalene	7	CO %	a
Paranitroaniline	3	Density: gm/cc	
Oil	1	Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	21	Refractive Index, $n_{20}^D$	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	a	$n_{25}^D$	
		$n_{30}^D$	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Crackles, snaps	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
Rifle Bullet Impact Test: 10 Trials	8 Trials*	100°C	11+
		120°C	
Explosions	% 90	135°C	
Partials	0	150°C	
Burned	0		
*Unaffected paper	10	200 Gram Bomb Sand Test:	
		Sand, gm	39.5
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	--	Minimum Detonating Charge, gm	
1	--	Mercury Fulminate	0.26
5	Decomposes 195	Lead Azide	--
10		Tetryl	--
15		Ballistic Mortar, % TNT: (a)	96
20		Trauzl Test, % TNT:	
75°C International Heat Test:		Plate Dent Test:	
% Loss in 48 Hrs	0.2	Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.3	Confined	
% Loss, 2nd 48 Hrs	0.3	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	
		Confinement	
Hygrosopicity: % 30°C, 90% RH	2.1	Condition	
Volatility:		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	

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

Preparation: (b)

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



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

Orinin:

Nitrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouze studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1838)). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References: <sup>51</sup>

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

(b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).

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

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

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



Octol, 70/30

Composition: %		Molecular Weight:	265
HMX	70	Oxygen Balance:	
TNT	30	CO, %	-38
		CO %	-7.5
		Density: gm/cc	Cast 1.80
		Melting Point: °C	
C/H Ratio		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg		Boiling Point: °C	
Picatinny Arsenal Apparatus, in.	18	Refractive Index, $n_{20}^D$	
Sample Wt, mg	26	$n_{25}^D$	
		$n_{50}^D$	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
		100°C	----
		120°C	0.37
		135°C	
		150°C	
Rifle Bullet Impact Test: Trials		200 Gram Bomb Sand Test:	
Explosions %		Sand, gm Exploratory	58.4
Partials			
Burned			
Unaffected			
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	----
5 Flames erratically	335	Lead Azide	0.30
10		Tetryl	----
15			
20		Ballistic Mortar, % TNT:	115
		Trauzl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test:	
		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs		Confined	
% Loss, 2nd 48 Hrs		Density, gm/cc	
Explosion in 100 Hrs		Brisance, % TNT	
		Detonation Rate:	
Flammability Index:		Confinement	None
		Condition	Cast
Hygroscopicity: %		Charge Diameter, in.	1.0
		Density, gm/cc	1.80
Volatility:		Rate, meters/second	8377



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;"><b>Glass Cones      Steel Cones</b></p> <p>Hole Volume                  Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Buff</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> HE projectile and bomb filler</p>
	<p><b>Method of Loading:</b> Cast</p>
	<p><b>Loading Density:</b> gm/cc 1.80</p>
	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p>
	<p><u>Work to Produce Rupture:</u> ft-lb/inch<sup>3</sup> *</p> <p>Average (10 tests) 1.55                  High 1.87                  Low 1.10</p> <p><u>Efflux Viscosity, Saybolt Seconds:</u> 5.9</p> <p>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</p>

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

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

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

Average Fragment Velocities at Various Altitudes\* (g)

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

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

Tensile Strength: \*

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

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

Modulus of Elasticity: \*

	lb/inch <sup>2</sup>
Average (10 tests)	73,200
High	79,300
Low	63,000

\*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

1/2 - 2	1297
2 - 5	665
5 - 10	497
10 - 25	661
25 - 50	471
50 - 75	247
75 - 150	322
150 - 750	295
750 - 2500	12
Total Number	4467

<b>Composition:</b> % HMX 75 TNT 25  C/H Ratio	Molecular Weight: 276	
	Oxygen Balance: CO, % -35 CO % -6.3	
	Density: gm/cc	Cast 1.81
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability test: cc/40 Hrs, at 90°C ---- 100°C ---- 120°C 0.39 135°C 150°C	
	Rifle Bullet Impact Test: 10 Trials % 3/16" Steel 1/8" Al	200 Gram Bomb Sand Test: Sand, gm Exploratory 62.1
Explosions 70 70 Partial 0 0 Burned 0 0 Unaffected 30 30	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
	Ballistic Mortar, % TNT: 116	
	Trough 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	
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:	

<b>Booster Sensitivity Test:</b> Condition Tetryl, gm Wox, in. for 50% Detonation Wax, gm Density, gm/cc	<b>Decomposition Equation:</b> Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/ mole (AH, kcal/mol) Temperature Range, °C Phase
<b>Heat of:</b> 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.	<b>Armor Plate Impact Test:</b>  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness  <b>500-lb General Purpose Bombs:</b>  Plate Thickness, inches  1 1¼ 1½ 1¾
<b>Specific Heat: cal/gm/°C</b> -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.	
<b>Burning Rate:</b> cm/sec	<b>Bomb Drop Test:</b>  <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>  Max Safe Drop, ft  <b>500-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order  <b>1000-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order
<b>Thermal Conductivity:</b> cal/sec/cm/°C	
<b>Coefficient of Expansion:</b> Linear, %/°C  Volume, %/°C	
<b>Hardness, Mohs' Scale:</b>	
<b>Young's Modulus:</b> E, dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc	
Compressive Strength: lb/inch <sup>2</sup> 1340 See below	
<b>Vapor Pressure:</b> °C mm Mercury <b>Compressive Strength: lb/inch<sup>2</sup></b> *** Average (10 tests) 1340 High 1560 Low 1040	<b>Ultimate Deformation: %</b> 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.

<p>Fragmentation test:</p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume                  Hole Depth</p>
	<p><b>Color:</b> <span style="float: right;">Buff</span></p>
	<p>Principal Uses: HE projectile and bomb filler</p>
	<p>Method of Loading: <span style="float: right;">Cast</span></p>
	<p>Loading Density: gm/cc <span style="float: right;">1.81</span></p>
<p>Fragment Velocity: ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p>Storage:</p> <p>Method <span style="float: right;">Dry</span></p> <p>Hazard Class (Quantity-Distance) <span style="float: right;">Class 9</span></p> <p>Compatibility Group <span style="float: right;">Group I</span></p> <p>Exudation</p>
<p>Blast (Relative to TNT):</p> <p>Air:                  Peak Pressure                  Impulse                  Energy</p> <p>Air, Confined:                  Impulse</p> <p>Under Water:                  Peak Pressure                  Impulse                  Energy</p> <p>Underground:                  Peak Pressure                  Impulse                  Energy</p>	<p><u>Work to Produce Rupture:</u> ft-lb/inch<sup>3</sup> *</p> <p style="text-align: right;">Average (10 tests)    1.31                  High    1.57                  Low    1.07</p> <p><u>Efflux Viscosity, Saybolt Seconds:</u> 9.0</p> <p>*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.</p>



Fragment Velocity Test: (a)

M26 Hand Grenade:

Composition B	4948
75/25 Cyclotol	4908
75/25 Octol	5124

Modulus of Elasticity:\*

	lb/inch <sup>2</sup>
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.

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

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: <sup>52</sup>

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

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

\* 58 word Standard Operating Procedure.

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

Composition:		Molecular Weight:	245
%		Oxygen Balance:	
RDX	90	CO, %	-62
Polystyrene (unmodified)	8.5	CO %	-18
Diocetylphthalate	1.5	Density: gm/cc Unpressed	0.81
		Pellet pressed at 30,000 psi	1.62
C/H Ratio		Melting Point: °C	
		Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b>	<u>Unpressed</u>	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.	15	$n_{30}^D$	
Sample Wt, mg	20		
Friction Pendulum test:		Vacuum Stability Test:	
Steel Shoe	Unaffected	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	----
		100°C	----
Rifle Bullet Impact test: 10 Trials *		120°C	0.41
Explosions	10	135°C	
Partials	90	150°C	
Burned	0	200 Gram Bomb Sand Test:	
Unaffected	0	Sand, gm	
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	---	Minimum Detonating Charge, gm	
1	---	Mercury Fulminate	
5 Smokes	275	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	0.00	Confined	
% Loss, 2nd 48 Hrs	0.00	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	
Hygroscopicity: %		Confinement	
		Condition	
		Charge Diameter, in.	
		Density, gm/cc	
		Rate, meters/second	
* Test procedure described in PATR No. 2247, May 1956.			

<p><b>Booster Sensitivity Test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (AH, kcal/mol)                  Temperature Range, °C                  Phase</p>									
<p><b>Heat of:</b>                  Combustion, cal/gm 3027                  Explosion, cal/gm 983                  Gas Volume, cc/gm                  Formation, cal/gm                  Fusion, cal/gm</p>	<p><b>Armor Plate Impact Test:</b></p> <p><b>60 mm Mortar Projectile:</b>                  50% Inert, Velocity, ft/sec                  Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b></p> <p>Plate Thickness, inches</p> <p>1                  1¼                  1½                  1¾</p>									
<p><b>Specific Heat:</b> col/gm/°C</p>	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p> <p>Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p> <p><b>1000-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p>									
<p><b>Burning Rate:</b>                  cm/sec</p>										
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C</p>										
<p><b>Coefficient of Expansion:</b>                  Linear, %/°C                  Volume, %/°C</p>										
<p><b>Hardness, Mohs' Scale:</b></p>										
<p><b>Young's Modulus:</b> See below                  E, dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>										
<p><b>Compressive Strength:</b> lb/inch<sup>2</sup> 2403 2149                  Percent 8.9 13.1</p>										
<p><b>Vapor Pressure:</b>                  °C mm Mercury</p> <p>Young's Modulus: * (a)      <u>Temperature</u></p> <table border="1"> <tr> <td></td> <td><u>Ambient</u></td> <td><u>95°C</u></td> </tr> <tr> <td>E, lb/inch<sup>2</sup> (avg of 5)</td> <td>39,953</td> <td>34,831</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.60</td> <td>1.57</td> </tr> </table>		<u>Ambient</u>	<u>95°C</u>	E, lb/inch <sup>2</sup> (avg of 5)	39,953	34,831	Density, gm/cc	1.60	1.57	
	<u>Ambient</u>	<u>95°C</u>								
E, lb/inch <sup>2</sup> (avg of 5)	39,953	34,831								
Density, gm/cc	1.60	1.57								

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> White</p> <p><b>Principal Uses:</b> High mechanical strength explosive</p> <p><b>Method of Loading:</b> Pressed</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																												
	Glass Cones	Steel Cones																																		
Hole Volume																																				
Hole Depth																																				
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b>      Pressed, psi x 10<sup>5</sup></p> <table border="0"> <tr> <td>0</td> <td>10</td> <td>20</td> <td>30</td> </tr> <tr> <td>1.10</td> <td>1.49</td> <td>1.59</td> <td>1.62</td> </tr> </table>	0	10	20	30	1.10	1.49	1.59	1.62																											
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table> <p><b>Rockwell Hardness, "R" Scale: (a)</b>  <u>1/2 inch diameter Penetrator, 60 Kg Load:</u></p> <table border="0"> <thead> <tr> <th><u>Pellet No.*</u></th> <th><u>Specific Gravity</u></th> <th><u>Hardness</u></th> </tr> </thead> <tbody> <tr><td>1</td><td>1.624</td><td>84</td></tr> <tr><td>2</td><td>1.623</td><td>90</td></tr> <tr><td>3</td><td>1.611</td><td>84</td></tr> <tr><td>4</td><td>1.600</td><td>80</td></tr> <tr><td>5</td><td>1.590</td><td>75</td></tr> <tr><td>6</td><td>1.571</td><td>73</td></tr> <tr><td>7</td><td>1.548</td><td>62</td></tr> <tr><td>8</td><td>1.524</td><td>49</td></tr> </tbody> </table> <p>*Pellets (Lot HOL-E-93) were 1-1/2 inches in diameter and 3/4 inch high.</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None	<u>Pellet No.*</u>	<u>Specific Gravity</u>	<u>Hardness</u>	1	1.624	84	2	1.623	90	3	1.611	84	4	1.600	80	5	1.590	75	6	1.571	73	7	1.548	62	8	1.524	49
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Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid  
Pellets\* to Initiation by Type II Special Blasting Caps (a)

Pellets	Gap (Distance From Base of Cap to Pellet), Inches						
	0.250	0.300	0.350	0.400	0.450	0.500	0.750
<u>PB-RDX with Pellet Density 1.55 gm/cc</u>							
No. of Trials	1	8	5	6	2	1	1
Average Depth of Plate Indentation, inches **	0.082	0.090	0.087	0.080	0.080	—	—
No. of Failures	0	1	3	4	1	1	1
<u>PB-RDX with Pellet Density 1.60 gm/cc</u>							
No. of Trials	3	8	9	4	3	5	2
Average Depth of Plate Indentation, inches **	0.090	0.089	0.087	0.084	0.087	0.075	—
No. of Failures	0	0	2	3	2	3	2
<u>98/2 RDX/Stearic Acid With Pellet Density 1.63 gm/cc</u>							
No. of Trials	5	3	5	5	5	5	5
Average Depth of Plate Indentation, inches **	0.109	0.096	0.095	0.092	0.097	0.087	—
No. of Failures	0	1	0	3	4	4	5

\* Pellets 0.92 inch diameter, 0.375 inch height.

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

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

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

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

PB-RDXPreparation:

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:

<u>Through U. S. Standard</u> 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<sub>2</sub>O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75°C by introducing steam into the jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10°C.

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

Origin:

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

Commission, Report No. 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: <sup>53</sup>

(a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, Characteristics of Polystyrene-Bonded RDX(PB-RDX), PAIR 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, PAIR 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.

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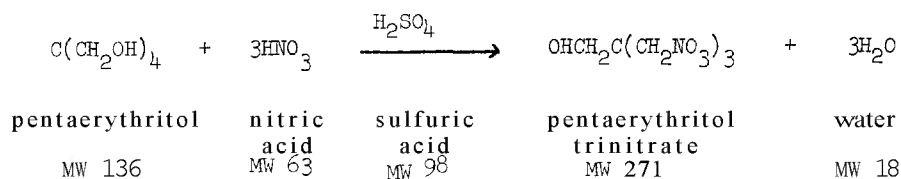
<sup>53</sup>See footnote 1, page 10.



Composition: % C 22.1 H 3.3 N 15.5 O 59.1 C/H Ratio 0.141	$  \begin{array}{c}  \text{CH}_2\text{ONO}_2 \\    \\  \text{HOCH}_2 - \text{C} - \text{CH}_2\text{ONO}_2 \\    \\  \text{CH}_2\text{ONO}_2  \end{array}  $	Molecular Weight: $(\text{C}_5\text{H}_9\text{N}_3\text{O}_{10})$	271
		Oxygen Balance: CO <sub>2</sub> % CO %	-27 3
		Density: gm/cc	1.54
		Melting Point: °C	26 to 28
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38		Boiling Point: °C 4 mm Hg Decomposes	130
		Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$	
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	---- 2.54 to 5.65
Rifle Bullet Impact Test: Trials Explosions % Partials Burned Unaffected		200 Gram Bomb Sand Test: Sand, gm	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl	
		Ballistic Mortar, % TNT:	
		Traurl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs		Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
Flammability Index:			
Hygroscopicity: %			
Volatility:			

Pentaerythritol Trinitrate (PETRIN)

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Color:</b> White</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><u>Absolute Viscosity, poises:</u></p> <table border="0"> <tr> <td>Temp, 17°C</td> <td>14.8</td> </tr> <tr> <td>23°C</td> <td>4.8</td> </tr> <tr> <td>28°C</td> <td>3.0</td> </tr> <tr> <td>36°C</td> <td>1.2</td> </tr> </table>	Temp, 17°C	14.8	23°C	4.8	28°C	3.0	36°C	1.2	<p><b>Principal Uses:</b> Explosive, propellant or igniter ingredient</p>	
Temp, 17°C	14.8									
23°C	4.8									
28°C	3.0									
36°C	1.2									
	<p><b>Method of Loading:</b></p>									
	<p><b>Loading Density:</b> gm/cc</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td></td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation	None	
Method	Dry									
Hazard Class (Quantity-Distance)										
Compatibility Group										
Exudation	None									
	<p>PETRIN esters are listed in reference (b) and most of these esters have been shown to have explosive properties.</p> <p>An infrared spectrophotometric procedure was developed for the determination of the acetone content of PETRIN (ref c). A 2.5 gm sample of PETRIN is dissolved in chloroform and the volume increased to 25 milliliters in a volumetric flask. The acetone content of the PETRIN solution is determined by its infrared absorption at 5.82<math>\mu</math> 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 6.02<math>\mu</math> maximum.</p> <p><u>Heat of:</u></p> <table border="0"> <tr> <td>Explosion, cal/gm</td> <td>1204</td> </tr> </table>	Explosion, cal/gm	1204							
Explosion, cal/gm	1204									

Preparation:

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<sub>3</sub> and the solid pentaerythritol were charged to the reactor and 80% H<sub>2</sub>SO<sub>4</sub> was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammonium carbonate, after which the PETRIN was precipitated by the addition of water. After filtration, the PETRIN was recovered from the filtrate by stripping off the solvent under vacuum. Yields by this process averaged about 40%.

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

The "C process," currently in use, involves essentially the simultaneous synthesis and extraction of PETRIN from the reaction mixture. 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, PETRIN 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<sub>2</sub> 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<sub>3</sub> and 80% H<sub>2</sub>SO<sub>4</sub> in 1955 (A. T. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

References<sup>54</sup>

- (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.

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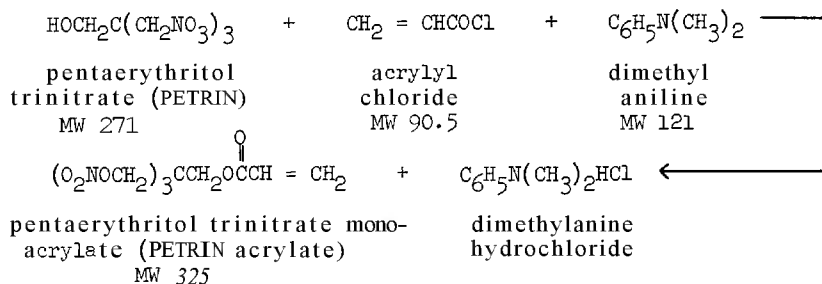
<sup>54</sup>See footnote 1, page 10.



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

Preparation:

(a)



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

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

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

PETRIN Acrylate Propellants:

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

A composition which presently appears most promising is as follows:

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

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

Reference:<sup>55</sup>

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

<sup>55</sup>See footnote 1, page 10.





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

<p><b>Fragmentation Test:</b> <u>50/50</u></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.65                  Charge Wt, lb 2.147</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 968</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.65                  Charge Wt, lb 0.872</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 650</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b>  <u>50/50 10/90 50/50 25/75</u>                  Glass Cones (f) Steel Cones (g)</p> <table border="1"> <tr> <td>Hole Volume</td> <td>157</td> <td>105</td> <td>149</td> <td>119</td> </tr> <tr> <td>Hole Depth</td> <td>116</td> <td>116</td> <td>131</td> <td>119</td> </tr> </table>	Hole Volume	157	105	149	119	Hole Depth	116	116	131	119
Hole Volume	157	105	149	119							
Hole Depth	116	116	131	119							
	<p><b>Color:</b> Yellow-white</p>										
	<p><b>Principal Uses:</b> Shaped charges, bursting charges, demolition blocks</p>										
	<p><b>Method of Loading:</b> Cast</p>										
	<p><b>Loading Density: gm/cc</b> <del>50/50 10/90</del>                  1.65 1.60</p>										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft 2810                  At 25½ ft 2580                  Density, gm/cc 1.66</p>	<p><b>Storage:</b>                  Method                  Hazard Class (Quantity-Distance) Class 9                  Compatibility Group Group I                  Exudation</p>										
<p><b>Blast (Relative to TNT):</b> (e)</p> <p><b>Air:</b>                  Peak Pressure 105                  Impulse 107                  Energy --</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Compatibility with Metals:</b>  <u>Dry:</u> Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium or nickel are not affected. Zinc plated steel is only slightly affected.  <u>Wet:</u> Stainless steel, aluminum and mild steel coated with acid-proof black paint are not affected. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with copper, cadmium, zinc or nickel are slightly affected.</p>										
<p><b>Eutectic Temperature, °C:</b> 76</p> <p>gn PETN/100 gn TNT                  76°C 13.0                  95°C 28.3</p>	<p><b>Effect of Temperature on Rate of Detonation:</b> (h)</p> <table border="1"> <tr> <td>16 hrs at, °C</td> <td><del>-54</del></td> <td>21</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.67</td> <td>1.66</td> </tr> <tr> <td>Rate, m/sec</td> <td>7470</td> <td>7440</td> </tr> </table>	16 hrs at, °C	<del>-54</del>	21	Density, gm/cc	1.67	1.66	Rate, m/sec	7470	7440	
16 hrs at, °C	<del>-54</del>	21									
Density, gm/cc	1.67	1.66									
Rate, m/sec	7470	7440									

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PEIN and TNT. In the slurry method PEIN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PEIN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In coprecipitation, PEIN 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 11, with the 50-50 PEIN/TNT mixture being the more important for bursting charges and booster-surround charges.

References:<sup>56</sup>

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

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

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

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

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

(f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract 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, PAIR No. 2363, November 1956.

(i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1360	1291	1212	1133	1284	1325	1436	1477	1388
1420	1451	1262	1193	2004		1466	1677	1598
1570	1651	1372	1213			1796	1737	1668
			1363					1838

<sup>56</sup>See footnote 1, page 10.

Composition: % C 19.0 H 2.5 N 17.7 O 60.8 C/H Ratio 0.134 <div style="text-align: center; margin-top: 10px;"> <math display="block">  \begin{array}{c}  \text{ONO}_2 \\    \\  \text{CH}_2 \\    \\  \text{O}_2\text{NO}-\text{CH}_2-\text{C}-\text{CH}_2-\text{ONO}_2 \\    \\  \text{CH}_2 \\    \\  \text{ONO}_2  \end{array}  </math> </div>	Molecular Weight: $(\text{C}_5\text{H}_8\text{N}_4\text{O}_{12})$	316
	Oxygen Balance: CO, % CO %	-10 15
	Density: gm/cc Cryst a 1	1.77
	Melting Point: °C	141
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	17 6 16	Boiling Point: °C Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$
Friction Pendulum Test: Steel Shoe Fiber Shoe	Crackles Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
Rifle Bullet Impact Test: 5 Trials * Explosions Partials Burned Unaffected *4.86% moisture in samples	% 100 0 0 0	0.5 11+
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 10 15 20	272 244 225 211 -- --	200 Gram Bomb Sand Test: Sand, gm 62.7
75°C International Heat test: % Loss in 48 Hrs	0.02	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl *Alternative initiating charges.
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	0.1 0.0 None	0.17* 0.03* --
Flammability Index: Will not continue to burn		Ballistic Mortar, % TNT: (a) 145
Hygroscopicity: % 30°C, 90% RH	0.0	Trauzl Test, % TNT: (b) 173
Volatility:	0.0	Plate Dent Test: (c) Method Condition Confined Density, gm/cc Brisance, % TNT
		A Pressed Yes 1.50 129
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
		None Pressed 1.00 1.70 8300

<p><b>Booster Sensitivity Test:</b></p> <p>Condition (c) Pressed</p> <p>Tetryl, gm 5</p> <p>Wax, in. for 50% Detonation</p> <p>Wax, gm 3</p> <p>Density, gm/cc 1.6</p>	<p><b>Decomposition Equation:</b></p> <table border="0"> <tr> <td></td> <td>(e)</td> <td>(e)</td> <td>(f)</td> </tr> <tr> <td>Oxygen, atoms/sec</td> <td><math>10^{19.8}</math></td> <td><math>10^{20.6}</math></td> <td><math>10^{23.1}</math></td> </tr> <tr> <td>(Z/sec)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Heat, kilocalorie/mole</td> <td>47.0</td> <td>50.9</td> <td>52.3</td> </tr> <tr> <td>(<math>\Delta H</math> kcal/mol)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Temperature Range, °C</td> <td>161-233</td> <td>108-120</td> <td>137-157</td> </tr> <tr> <td>Phase</td> <td>Liquid</td> <td>Solid</td> <td>At melting point</td> </tr> </table>		(e)	(e)	(f)	Oxygen, atoms/sec	$10^{19.8}$	$10^{20.6}$	$10^{23.1}$	(Z/sec)				Heat, kilocalorie/mole	47.0	50.9	52.3	( $\Delta H$ kcal/mol)				Temperature Range, °C	161-233	108-120	137-157	Phase	Liquid	Solid	At melting point
	(e)	(e)	(f)																										
Oxygen, atoms/sec	$10^{19.8}$	$10^{20.6}$	$10^{23.1}$																										
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Temperature Range, °C	161-233	108-120	137-157																										
Phase	Liquid	Solid	At melting point																										
<p><b>Heat of:</b></p> <p>Combustion, cal/gm 1960</p> <p>Explosion, cal/gm 1385</p> <p>Gas Volume, cc/gm 790</p> <p>Formation, cal/gm 383</p> <p>Fusion, cal/gm</p>	<p><b>Armor Plate Impact Test:</b></p> <p><b>60 mm Mortar Projectile:</b></p> <p>50% Inert, Velocity, ft/sec</p> <p>Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b></p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>																												
<p><b>Specific Heat:</b> cal/gm/°C (d)</p> <p>Room Temperature 0.26</p>	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b></p> <p>Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p><b>1000-lb General Purpose Bomb vs Concrete:</b></p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>																												
<p><b>Burning Rate:</b></p> <p>cm/sec</p>																													
<p><b>Thermal Conductivity:</b></p> <p>cal/sec/cm/°C</p>																													
<p><b>Coefficient of Expansion:</b></p> <p>Linear, %/°C</p> <p>Volume, %/°C</p>																													
<p><b>Hardness, Mohs' Scale:</b> 1.9</p>																													
<p><b>Young's Modulus:</b></p> <p>E, dynes/cm<sup>2</sup></p> <p>E, lb/inch<sup>2</sup></p> <p>Density, gm/cc</p>																													
<p><b>Compressive Strength:</b> lb/inch<sup>2</sup></p>																													
<p><b>Vapor Pressure:</b></p> <p>"C mm Mercury</p>																													

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> White</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b>                  Class A - Detonating fuse and boosters                  Class B - Priming compositions</p>									
	<p><b>Method of Loading:</b></p>									
	<table border="0"> <tr> <td><b>Loading Density:</b> gm/cc</td> <td style="text-align: right;">psi x 10<sup>3</sup></td> </tr> <tr> <td style="text-align: center;">3      5      10      20      30      40</td> <td></td> </tr> <tr> <td style="text-align: center;">1.37   1.58   1.64   1.71   1.73   1.74</td> <td></td> </tr> </table>	<b>Loading Density:</b> gm/cc	psi x 10 <sup>3</sup>	3      5      10      20      30      40		1.37   1.58   1.64   1.71   1.73   1.74				
<b>Loading Density:</b> gm/cc	psi x 10 <sup>3</sup>									
3      5      10      20      30      40										
1.37   1.58   1.64   1.71   1.73   1.74										
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: right;">Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: right;">Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td style="text-align: right;">Group M (wet)</td> </tr> <tr> <td>Exudation</td> <td style="text-align: right;">None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M (wet)	Exudation	None	
Method	Wet									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group M (wet)									
Exudation	None									
	<table border="0"> <tr> <td><b>Bulk Modulus at Room Temperature (25°-30°C) :</b></td> <td style="text-align: right;">(1)</td> </tr> <tr> <td>Dynes/cm<sup>2</sup> x 10<sup>-10</sup></td> <td style="text-align: right;">4.60</td> </tr> <tr> <td>Density, gm/cc</td> <td style="text-align: right;">1.77</td> </tr> </table>	<b>Bulk Modulus at Room Temperature (25°-30°C) :</b>	(1)	Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>	4.60	Density, gm/cc	1.77			
<b>Bulk Modulus at Room Temperature (25°-30°C) :</b>	(1)									
Dynes/cm <sup>2</sup> x 10 <sup>-10</sup>	4.60									
Density, gm/cc	1.77									

Compatibility with Metals:

Dry: Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PEIN to electrostatic discharge, joules: Through 100 Mesh: (g)

Unconfined	0.06
Confined	0.21

Solubility, grams of PEIN per 100 grams (%) of: (h)

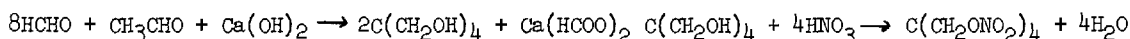
<u>Trichlorethylene or Alcohol</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.070	0	14.37	0	0.150	0	0.150
20	0.195	20	24.95	20	0.450	20	0.430
40	0.415	40	30.56	40	1.160	40	0.620
60	1.205	60	42.68	80	7.900	60	2.490
						80	5.850
						100	15.920
						112	30.900

<u>Methyl acetate</u>		<u>Ether</u>		<u><del>β</del>-Ethoxy-ethyl- acetate</u>		<u>Chlorobenzene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	13	0	0.200	20	1.5	20	0.35
30	17	20	0.340	30	4.1	30	2.8
40	22	34.7	0.450	40	7.6	40	6.1
50	31			50	11.2	50	9.2
				60	14.2	60	12.2

<u>Ethylendichloride</u>		<u>Methanol</u>		<u>Tetrachloroethane</u>		<u>Carbon tetrachloride</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
10	0.9	20	0.46	20	0.18	20	0.096
30	1.5	40	1.15	30	0.27	30	0.108
50	2.6	60	2.6	40	0.40	40	0.118
				50	0.58	50	0.121

<u>Isopropanol</u>		<u>Isobutanol</u>		<u>Chloroform</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
15	0.02	20	0.27	20	0.09	80	19.3
20	0.04	30	0.31			85	25.0
30	0.15	40	0.39			90	32.1
40	0.36	50	0.52			95	39.5
50	0.46					100	48.6
						105	58.2
						110	70.0
						115	87.8
						120	115
						125	161

Eutetic of the system PEIN-TNT is about 13% PEIN and 87% TNT at 76°C.

Preparation:(Nitroglycerin and Nitroglycerin Explosives, Naoum)

1. In this preparation 1940 gm of formaldehyde and 600 gm of acetaldehyde are dissolved in 90 liters of water containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with oxalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaerythritol, melting point 235°-240°C are obtained. Purification is readily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric acid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good agitation. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PEIN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and ease of combustion (German Patent 81,664 (1894)). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengstoffw 11, 112, 182 (1916) and 24, 259 (1929)). PEIN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PEIN 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 PEIN, of a solution of 1 part sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) in 2 parts water heated to 80°C. The aqueous solution should be added at such a rate that the acetone solution does not boil. After mixing is complete continue stirring for one-half hour.



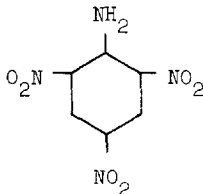
References<sup>57</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests: Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph. Naoum, Z ges Schiess - Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) 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 PEIN:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
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									

<sup>57</sup>See footnote 1, page 10.

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

<p><b>Frogmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Color:</b> Yellow</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Principal Uses:</b> High temperature heat resistant explosive</p>
	<p><b>Method of Loading:</b> Pressed</p>
	<p><b>Loading Density:</b> gm/cc At 50,000 psi 1.72</p>
	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation None</p>
	<p><b>Solubility:</b></p> <p>Insoluble in water, slightly soluble in alcohol and ether. Soluble in hot glacial acetic acid, hot ethyl acetate and in benzene and acetone.</p> <p><b>Heat of:</b></p> <p>Combustion, cal/gm (a) 2962 Explosion, cal/gm 564 Formation, cal/gm (a) 131</p>

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<sub>2</sub>SO<sub>4</sub> at about 5°C with concentrated HNO<sub>3</sub> (Ber 41, 3091 (1908)). Holleman gives details of the preparation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference:<sup>58</sup>

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

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<sup>58</sup>See footnote 1, page 10.

Composition: % Explosive D      52 TNT                48  C/H Ratio	Molecular Weight: 236	
	Oxygen Balance: CO <sub>2</sub> %      -63 CO %        -19	
	Density: gm/cc	Cast      1.62
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm      100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in.      17 Sample Wt, mg                              19	Boiling Point: °C	
	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$	
Friction Pendulum Test: Steel Shoe                                  Unaffected Fiber Shoe                                  Unaffected	Vacuum Stability Test: cc/40 Hrs, at: 90°C 100°C    0.37 120°C    0.68 135°C    -- 150°C    0.7	
	Rifle Bullet Impact Test:      Trials  Explosions                              0 Partial                                    0 Burned                                    40 Unaffected                              60	200 Gram Bomb Sand Test: Sand, gm                                  45.9
Explosion Temperature:      °C Seconds, 0.1 (no cap used)      456 1      354 5      Decomposes      285 10     265 15     260 20     255	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide                                  0.20 Tetryl    0.05	
	Ballistic Mortar, % TNT:      (a)      100	
	Traurl Test, % TNT:	
75°C International Heat Test: % Loss in 48 Hrs                          0.0	Plate Dent Test:                          (b) Method    B Condition                                      Cast Confined                                        No Density, gm/cc                              1.63 Brisance, % TNT                            100	
100°C Heat Test: % Loss, 1st 48 Hrs                          0.0 % Loss, 2nd 48 Hrs                          0.05 Explosion in 100 Hrs                        None	Detonation Rate:                          (b) Confinement                                  None Condition                                      Cast Charge Diameter, in.                        1.0 Density, gm/cc                              1.63 Rate, meters/second                        6970	
	Flammability Index:	
Hygroscopicity: % 30°C, 90%RH      0.02		
Volatility:		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.61                  Charge Wt, lb 2.075</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 769</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.61                  Charge Wt, lb 0.850</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 487</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft 2590                  At 25½ ft 2320                  Density, gm/cc 1.62</p>	<p><b>Color:</b> Brown-yellow</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure 100                  Impulse 100                  Energy --</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> AP, SAP projectiles and bombs</p>									
<p><b>Bomb Drop Test:</b></p> <p>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft 10,000-12,000</p>	<p><b>Method of Loading:</b> Cast</p>									
	<p><b>Loading Density: gm/cc</b> 1.62</p>									
	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td style="text-align: center;">Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: center;">Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td style="text-align: center;">Group I</td> </tr> <tr> <td>Exudation</td> <td style="text-align: center;">None at 65°C</td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None at 65°C	
Method	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group I									
Exudation	None at 65°C									
	<p><b>Preparation:</b></p> <p>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.</p> <p><b>Origin:</b></p> <p>Developed during World War II as an insensitive, melt-loaded AP bomb and projectile filler</p>									
	<p><b>Booster Sensitivity Test:</b> (c)</p> <table border="0"> <tr> <td>Condition</td> <td style="text-align: center;">Cast</td> </tr> <tr> <td>Tetryl, gn</td> <td style="text-align: center;">100</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td style="text-align: center;">1.00</td> </tr> <tr> <td>Density, gm/cc</td> <td style="text-align: center;">1.63</td> </tr> </table>	Condition	Cast	Tetryl, gn	100	Wax, in. for 50% Detonation	1.00	Density, gm/cc	1.63	
Condition	Cast									
Tetryl, gn	100									
Wax, in. for 50% Detonation	1.00									
Density, gm/cc	1.63									

References: <sup>59</sup>

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

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

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

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

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

<u>0</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1470	1885	1466	1737	1838	1729
		1796	1797		
		1956			

<sup>59</sup>See footnote 1, page 10.

Composition: % C 31.5 H 1.3 N 18.3 O 48.9 C/H Ratio 0.656			Molecular Weight: (C <sub>6</sub> H <sub>3</sub> N <sub>3</sub> O <sub>7</sub> ) 229	
			Oxygen Balance: CO, % -45 CO % -3.5	
		Density: gm/cc Crystal 1.76		
		Melting Point: °C 122		
		Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 85 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 17		Boiling Point: °C		
		Refractive Index, n <sub>20</sub> <sup>o</sup> n <sub>25</sub> <sup>o</sup> n <sub>30</sub> <sup>o</sup>		
Friction Pendulum Test: Steel Shoe Fiber Shoe		Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 0.2 120°C 0.5 135°C 150°C		
Rifle Bullet Impact Test: Trials Explosions 0 Partial 60 Burned 40 Unaffected 0		200 Gram Bomb Sand Test: Sand, gm 48.5		
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 320 10 15 20		Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.26* Lead Azide 0.24* Tetryl *Alternative initiating charges.		
		Ballistic Mortar, % TNT: (a) 112		
		Traurl Test, % TNT: (b) 101		
75°C International Heat Test: % Loss in 48 Hrs 0.05		Plate Dent Test: (c) Method A Condition Pressed Confined No Density, gm/cc 1.50 Brisance, % TNT 107		
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.09 Explosion in 100 Hrs None				
Flammability Index:		Detonation Rate: (d) Confinement Unconfined		
Hygroscopicity: % 30°C, 90% RH 0.04		Condition Pressed Cast Charge Diameter, in. 1.0 1.25 Density, gm/cc 1.64 1.71 Rate, meters/second 5270 7350		
Volatility:				



<p>Booster Sensitivity test: (c)</p> <table border="1"> <tr> <td>Condition</td> <td>Pressed</td> <td>Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>10</td> <td>5</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td></td> <td></td> </tr> <tr> <td>Wax, gm</td> <td>2</td> <td>0</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.6</td> <td>1.7</td> </tr> </table>	Condition	Pressed	Cast	Tetryl, gm	10	5	Wax, in. for 50% Detonation			Wax, gm	2	0	Density, gm/cc	1.6	1.7	<p>Decomposition Equation:</p> <p>Oxygen, atoms/sec (Z/sec)</p> <p>Heat, kilocalorie/mole (<math>\Delta H</math>, kcal/mol)</p> <p>Temperature Range, °C</p> <p>Phase</p>
Condition	Pressed	Cast														
Tetryl, gm	10	5														
Wax, in. for 50% Detonation																
Wax, gm	2	0														
Density, gm/cc	1.6	1.7														
<p>Heat of:</p> <table border="1"> <tr> <td>Combustion, cal/gm</td> <td>2672</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1000</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>675</td> </tr> <tr> <td>Formation, cal/gm</td> <td>248</td> </tr> <tr> <td>Fusion, cal/gm (e)</td> <td>20.4</td> </tr> <tr> <td>Temperature, °C</td> <td>122</td> </tr> </table>	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	<p>Armor Plate Impact test:</p> <p>60 mm Mortar Projectile:</p> <p>50% Inert, Velocity, ft/sec</p> <p>Aluminum Fineness</p> <p>500-lb General Purpose Bombs:</p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>			
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															
<p>Specific Heat: cal/gm/°C (e)</p> <table border="1"> <tr> <td>°C</td> <td></td> </tr> <tr> <td>0</td> <td>0.235</td> </tr> <tr> <td>30</td> <td>0.258</td> </tr> <tr> <td>60</td> <td>0.282</td> </tr> <tr> <td>90</td> <td>0.310</td> </tr> <tr> <td>120</td> <td>0.337</td> </tr> </table>	°C		0	0.235	30	0.258	60	0.282	90	0.310	120	0.337	<p>Bomb Drop test:</p> <p>17, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft</p> <p>500-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p>1000-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>			
°C																
0	0.235															
30	0.258															
60	0.282															
90	0.310															
120	0.337															
<p>Burning Rate:</p> <p>cm/sec</p>																
<p>Thermal Conductivity: (f)</p> <table border="1"> <tr> <td>col/sec/cm/°C</td> <td><math>6.24 \times 10^{-4}</math></td> </tr> <tr> <td>Density, gm/cc</td> <td>1.406</td> </tr> </table>	col/sec/cm/°C	$6.24 \times 10^{-4}$	Density, gm/cc	1.406												
col/sec/cm/°C	$6.24 \times 10^{-4}$															
Density, gm/cc	1.406															
<p>Coefficient of Expansion:</p> <p>Linear, %/°C</p> <p>Volume, %/°C</p>																
<p>Hardness, Mohs' Scale:</p> <p>2.1</p>																
<p>Young's Modulus:</p> <p>E, dynes/cm<sup>2</sup></p> <p>E, lb/inch<sup>2</sup></p> <p>Density, gm/cc</p>																
<p>Compressive Strength: lb/inch<sup>2</sup></p>																
<p>Vapor Pressure:</p> <table border="1"> <tr> <td>°C</td> <td>mm Mercury</td> </tr> <tr> <td>195</td> <td>2</td> </tr> <tr> <td>255</td> <td>50</td> </tr> </table>	°C	mm Mercury	195	2	255	50										
°C	mm Mercury															
195	2															
255	50															

<p>Fragmentation Test:</p> <p><b>90 mm HE, M71 Projectile, lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td style="text-align: center;"><b>Gloss Cones</b></td> <td style="text-align: center;"><b>Steel Cones</b></td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p>Cobr: <span style="float: right;">Yellow</span></p> <hr/> <p><b>Principal Uses:</b> Formerly projectile filler, now explosive admixture; and for the manufacture of Explosive D</p> <hr/> <p><b>Method of Loading:</b> <span style="float: right;">Pressed</span></p>		<b>Gloss Cones</b>	<b>Steel Cones</b>	Hole Volume			Hole Depth		
	<b>Gloss Cones</b>	<b>Steel Cones</b>								
Hole Volume										
Hole Depth										
<p>Fragment Velocity: ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<table border="0"> <tr> <td style="text-align: left;">Loading Density: gm/cc</td> <td style="text-align: right;">psi x 10<sup>3</sup></td> </tr> <tr> <td style="text-align: center;">3      5      10</td> <td style="text-align: center;">12    15    20</td> </tr> <tr> <td style="text-align: center;">1.40   1.50   1.57</td> <td style="text-align: center;">1.59   1.61   1.64</td> </tr> </table>	Loading Density: gm/cc	psi x 10 <sup>3</sup>	3      5      10	12    15    20	1.40   1.50   1.57	1.59   1.61   1.64			
Loading Density: gm/cc	psi x 10 <sup>3</sup>									
3      5      10	12    15    20									
1.40   1.50   1.57	1.59   1.61   1.64									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure  <b>Impulse</b>                  Energy</p> <p>Air, Confined                  Impulse</p> <p>Under Water:                  Peak Pressure                  Impulse                  Energy</p> <p>Underground:  <b>Peak Pressure</b>                  Impulse                  Energy</p>	<p>Storage:</p> <table border="0"> <tr> <td><b>Method</b></td> <td style="text-align: right;">Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td style="text-align: right;">Class 9</td> </tr> <tr> <td>Compotibility Group</td> <td style="text-align: right;">Group I</td> </tr> <tr> <td>Exudation</td> <td style="text-align: right;">None</td> </tr> </table>	<b>Method</b>	Dry	Hazard Class (Quantity-Distance)	Class 9	Compotibility Group	Group I	Exudation	None	
<b>Method</b>	Dry									
Hazard Class (Quantity-Distance)	Class 9									
Compotibility Group	Group I									
Exudation	None									

Picric Acid

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

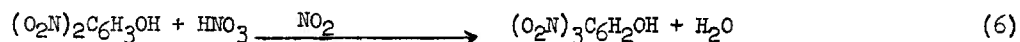
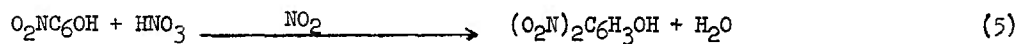
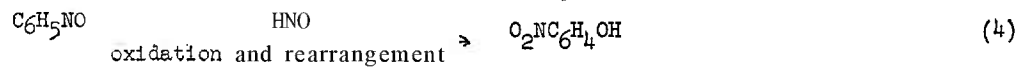
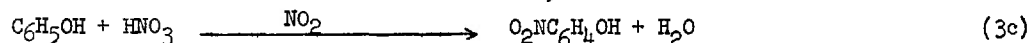
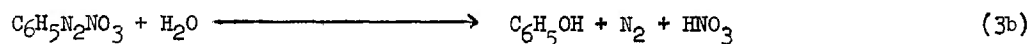
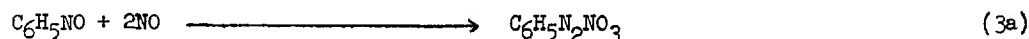
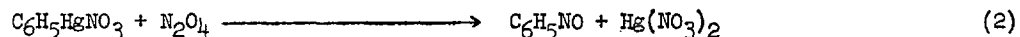
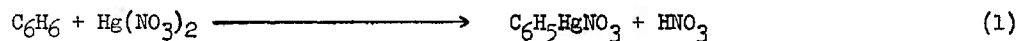
<u>Water</u>		<u>Alcohol</u>		<u>Benzene</u>		<u>Toluene</u>		<u>Ether</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.85	0	4.5	0	~ 2	20	~ 13	20	~ 3
20	1.17	20	6.9	20	9.6	60	~ 30	34.7	3.96
40	1.88	40	12.0	40	27.5				
60	2.98			60	59				
80	4.53								
100	7.1								

<u>Chloroform</u>		<u>Ethyl acetate</u>		<u>Carbon tetrachloride</u>		<u>Pyridine</u>		<u>Acetone</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	- 2	20	42	20	~ 0.07	10	24	20	125
60	~ 6	30	50	60	~ 0.4	30	37.5	30	137
		40	58			50	58	40	164
		50	69					50	208

<u>Methanol</u>		<u>Isopropyl alcohol</u>		<u>Propanol-1</u>		<u>Carbon disulfide</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	14	10	6.4	0	2.4	20	0.12
20	19	30	9.8	20	3.3	30	0.16
40	31	50	15.5	40	5.4		
50	41			50	7.4		

Preparation: (Summary Report of NDRC, Mv 8, Vol I)

The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the oxynitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the overall rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the oxynitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of oxynitration. The oxynitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of benzene is probably the most critical variable affecting the proportion of neutral nitro-compounds to 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 111, 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 ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) 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-Sprengstoff, pp. 181, 229, 267 (27 June 1932).

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

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

M. D. 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:

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1651	132	1383	694	65	266	1347	1118	1549
	582		764	425	556	1557		
	1172		874	1585	926			
	1352				976			
	1372				986			
					1446			
					1556			

<sup>60</sup>See footnote 1, page 10.

Composition: %  PETN 81  Gulf Crown E Oil 19  C/H Ratio	Molecular Weight:	310	
	Oxygen Balance:		
	CO, %	-74	
	CO %	-31	
	Density: gm/cc	Hand tamped	1.35
	Melting Point: °C		
	Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 27	Boiling Point: °C		
	Refractive Index, $n_{20}^D$		
	$n_{25}^D$		
	$n_{30}^D$		
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test:		
	cc/40 Hrs, at		
Rifle Bullet Impact Test: Trials  Explosions 0 Partials 0 Burned 0 Unaffected 100	90°C		
	100°C	0.48	
	120°C	16 hours	11+
	135°C		
	150°C		
	200 Gram Bomb Sand Test:		
	Sand, gm	41.6	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes* 10 15 20 *No value obtained.	Sensitivity to Initiation:		
	Minimum Detonating Charge, gm		
	Mercury Fulminate	0.20*	
	Lead Azide	0.20*	
	Tetryl		
	*Alternative initiating charges.		
	Ballistic Mortar, % TNT:		
	Trauzl Test, % TNT:		
75°C International Heat Test: % Loss in 48 Hrs	Plate Dent Test:	(a)	
	Method	B	
100°C Heat Test: % Loss, 1st 48 Hrs 0.17 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	Condition	Hand tamped	
	Confined	No	
	Density, gm/cc	1.33	
	Brisance, % TNT	76	
Flammability Index:	Detonation Rate:		
	Confinement	None	
Hygroscopicity: % 30°C, 90% RH 0.02	Condition	Hand tamped	
	Charge Diameter, in.	1.0	
Volatility:	Density, gm/cc	1.37	
	Rate, meters/second	7075	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>          Density, gm/cc 1.33          Charge Wt, lb 1.723</p> <p><b>Total No. of Fragments:</b>          For TNT 703          For Subject HE 519</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>          Density, gm/cc 1.39          Charge Wt, lb 0.735</p> <p><b>Total No. of Fragments:</b>          For TNT 514          For Subject HE 428</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume          Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec          At 9 ft          At 25½ ft          Density, gm/cc</p>	<p><b>Color:</b></p> <p><b>Principal Uses:</b> Plastic demolition explosive</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>          Peak Pressure          Impulse          Energy</p> <p><b>Air, Confined:</b>          Impulse</p> <p><b>Under Water:</b>          Peak Pressure          Impulse          Energy</p> <p><b>Underground:</b>          Peak Pressure          Impulse          Energy</p> <p><u>Preparation:</u>          PIPE is manufactured by simple mechanical mixing of PETN in oil.</p>	<p><b>Method of Loading:</b> Hand tamped</p> <p><b>Loading Density:</b> gm/cc 1.35</p> <p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p> <p><u>Origin:</u>          PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United States during World War 11.</p> <p><u>References:</u><sup>61</sup></p> <p>(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III-Miscellaneous Sensitivity Tests; Performance Tests</u>, OSRD Report No. 5746, 27 December 1945.</p> <p>(b) S. Livingston, <u>Properties of Explosives RIPE, PIPE and PEP-3</u>, Picatinny Arsenal Technical Report 1517, 24 April 1945.</p>

<sup>61</sup>See footnote 1, page 10.

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



<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> <th>(a)</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td>114</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td>103</td> <td></td> <td></td> </tr> </tbody> </table>		Glass Cones	Steel Cones	(a)	Hole Volume	114			Hole Depth	103		
		Glass Cones	Steel Cones	(a)									
	Hole Volume	114											
	Hole Depth	103											
	<p><b>Color:</b></p> <p>Light yellow</p>												
<p><b>Principal Uses:</b></p>													
<p><b>Method of Loading:</b></p> <p>Cast</p>													
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b></p>												
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><b>Preparation:</b>  Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TNT.</p>	<p><b>Storage:</b></p> <table border="1"> <tbody> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compotibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </tbody> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compotibility Group	Group I	Exudation					
	Method	Dry											
	Hazard Class (Quantity-Distance)	Class 9											
	Compotibility Group	Group I											
	Exudation												
<p><b>Origin:</b>  An explosive containing 70% lead nitrate and 30% TNT has been used in Belgium under the name of "Marcarite." <u>References:</u> <sup>62</sup></p>													
<p>(a) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition</u>, NDRC Contract W-672-ORD-5723.</p>													
<p>(b) <u>Thorpe's Dictionary of Applied Chemistry</u>, Fourth Edition, Vol IV, Longmans, Green and Company, London - New York - Toronto, p. 464.</p>													

<sup>62</sup>See footnote 1, page 10.

Composition: % Nitromethane            100        * Ethylenediamine        --            5 *The mixture 95/5 Nitromethane/Ethylenediamine is designated PLX (for Picatinny Liquid Explosive). See note under <u>Storage</u> .  C/H Ratio			Molecular Weight: $\frac{100}{61}$ $\frac{95/5}{61}$
			Oxygen Balance: CO, %                            -39                -48 CO %                             -13                -21
			Density: gm/cc                1.14                1.12
			Melting Point: °C            -29
			Freezing Point: °C
Impact Sensitivity, 2 Kg Wt:	<u>100</u>	<u>95/5</u>	Boiling Point: °C            101
Bureau of Mines Apparatus, cm	100+	100+	Refractive Index, $n_{20}^D$ $n_{25}^D$ $n_{30}^D$
Sample Wt 20 mg			
Picatinny Arsenal Apparatus, in.			
Sample Wt, mg	20	20	Vacuum Stability Test:
friction Pendulum Test:			cc/40 Hrs, at
Steel Shoe	Unaffected		90°C
Fiber Shoe	Unaffected		100°C
Rifle Bullet Impact Test: 10 Trials	5 Trials		120°C
Explosions	%	%	135°C
Partials	0	0	150°C
Burned	0	0	200 Gram Bomb Sand Test:
Unaffected	100	100	Sand, gm $\frac{100}{8.1}$ $\frac{95/5}{50.6}$
Explosion Temperature:	°C	°C	Sensitivity to Initiation:
Seconds, 0.1	<u>100</u>	<u>95/5</u>	Minimum Detonating Charge, gm
1			Mercury Fulminate
5	430	430	Lead Azide
10			Tetryl
15			Ballistic Mortar, % TNT:    134
20			Trauzl Test, % PA            127
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:            1/32"*            1/32"*
Hygroscopicity: %			Confinement                Glass                Glass
Volatility:			Condition                    Liquid                Liquid
			Charge Diameter, in.    1.25                0.94
			Density, gm/cc            1.14                1.12
			* Turbulence meters/seconds    6210                6165

<p>Booster Sensitivity Test: <u>Nitromethane</u></p> <p>Condition</p> <p>Tetryl, gm</p> <p>Wax, in. for 50% Detonation</p> <p>Wax, gm</p> <p>Density, gm/cc</p>	<p>Decomposition Equation: (d) <u>Nitromethane</u></p> <p>Oxygen, atoms/sec <math>10^{14.6}</math></p> <p>(Z/sec)</p> <p>Heat, kilocalorie/mole 56.6</p> <p>(AH, kcal/mol)</p> <p>Temperature Range, °C 380-430</p> <p>Phase Gaseous</p>						
<p>Heat of: (a)</p> <p>Combustion, cal/gm 2830</p> <p>Explosion, cal/gm</p> <p>Gas Volume, cc/gm</p> <p>Formation, cal/gm -348</p> <p>Fusion, cal/gm</p> <p>Vaporization, cal/gm 149</p>	<p>Armor Plate Impact Test:</p> <p>60 mm Mortar Projectile:</p> <p>50% Inert, Velocity, ft/sec</p> <p>Aluminum Fineness</p> <p>500-lb General Purpose Bombs:</p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>						
<p>Specific Heat: cal/gm/°C (b)</p> <p><math>C = 0.4209 - 0.000076t + 0.0000061t^2</math></p> <p>P for 15°C to 70°C</p>	<p>Bomb Drop Test:</p> <p>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft</p> <p>500-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p>1000-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>						
<p>Burning Rate:</p> <p>cm/sec</p>							
<p>Thermal Conductivity:</p> <p>cal/sec/cm/°C</p>							
<p>Coefficient of Expansion:</p> <p>Linear, %/°C</p> <p>Volume, %/°C</p>							
<p>Hardness, Mohs' Scale:</p>							
<p>Young's Modulus:</p> <p>E, dynes/cm<sup>2</sup></p> <p>E, lb/inch<sup>2</sup></p> <p>Density, gm/cc</p>							
<p>Compressive Strength: lb/inch<sup>2</sup></p>							
<p>Vapor Pressure: (c)</p> <table border="0"> <tr> <td>°C</td> <td>mm Mercury</td> </tr> <tr> <td>70</td> <td>258</td> </tr> <tr> <td>85</td> <td>444</td> </tr> </table>	°C	mm Mercury	70	258	85	444	
°C	mm Mercury						
70	258						
85	444						

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> Hole Volume Hole Depth																		
	<p><b>Color:</b> Light yellow</p>																		
	<p><b>Principal Uses:</b> Minefield clearing</p>																		
	<p><b>Method of Loading:</b> Pumping</p>																		
	<p><b>Loading Density: gm/cc</b></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 60%;"></td> <td style="text-align: center;"><u>100</u></td> <td style="text-align: center;"><u>95/5</u></td> </tr> <tr> <td></td> <td style="text-align: center;">1.14</td> <td style="text-align: center;">1.12</td> </tr> </table>		<u>100</u>	<u>95/5</u>		1.14	1.12												
	<u>100</u>	<u>95/5</u>																	
	1.14	1.12																	
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method      Components stored separately;                  mixed only when ready to use</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation</p>																		
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  impulse                  Energy</p>	<table style="width: 100%; border: none;"> <tr> <td style="width: 60%;"><u>Minimum Propagating</u></td> <td style="text-align: center;"><u>100</u></td> <td style="text-align: center;"><u>95/5</u></td> </tr> <tr> <td><u>Thickness. in:</u></td> <td style="text-align: center;">0.5</td> <td style="text-align: center;">0.063</td> </tr> <tr> <td><u>Viscosity centipoises:</u></td> <td colspan="2" style="text-align: center;">(e)</td> </tr> <tr> <td>Temp, 10°C</td> <td style="text-align: center;">0.748</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">25°C</td> <td style="text-align: center;">0.625</td> <td></td> </tr> <tr> <td style="padding-left: 20px;">40°C</td> <td style="text-align: center;">0.533</td> <td></td> </tr> </table>	<u>Minimum Propagating</u>	<u>100</u>	<u>95/5</u>	<u>Thickness. in:</u>	0.5	0.063	<u>Viscosity centipoises:</u>	(e)		Temp, 10°C	0.748		25°C	0.625		40°C	0.533	
	<u>Minimum Propagating</u>	<u>100</u>	<u>95/5</u>																
	<u>Thickness. in:</u>	0.5	0.063																
	<u>Viscosity centipoises:</u>	(e)																	
	Temp, 10°C	0.748																	
25°C	0.625																		
40°C	0.533																		
	<p><b>Compatibility with Metals:</b></p> <p>Stainless steel, mild steel and duriron                  not affected; corrodes brass.</p>																		

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:<sup>63</sup>

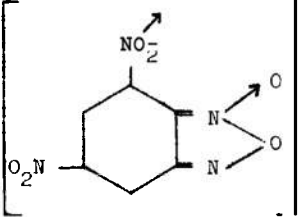
- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitroparaffins," *Ind Engr Chem* 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," *J Am Chem Soc* 47, 2644 (1925).
- (c) L. Medard, "Explosive Properties of Nitromethane," *Mém poudr* 33, 125 (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:

<u>0</u>	<u>1</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1660	1681 1831	2113	1565	2016	1747	1708	1619

<sup>63</sup>See footnote 1, page 10.

Potassium Dinitrobenzfuroxan (KDNEF)

<b>Composition:</b> % C 27.3 H 0.4 N 21.2 O 36.3 K 14.8  C/H Ratio 0.416		<b>Molecular Weight:</b> (KC <sub>6</sub> H <sub>4</sub> N <sub>4</sub> O <sub>6</sub> ) 225
		<b>Oxygen Balance:</b> CO <sub>2</sub> % -60 CO % -18
		<b>Density:</b> gm/cc 2.21
		<b>Melting Point:</b> °C Explodes 210
		<b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm *- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 (11b wt) 6 Sample Wt, mg 7		<b>Boiling Point:</b> °C
		<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
<b>Friction Pendulum Test:</b> Steel Shoe Explodes Fiber Shoe Explodes		<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected		<b>200 Gram Bomb Sand Test:</b> Sand, gm 44.8 43.6 Black powder fuse 9.5
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 250 10		<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate 0.30 0.20 Lead Azide 0.10 Tetryl
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> % 30°C, 75% RH 0.11 30°C, 90% RH 0.27		
<b>Volatility:</b>		

<p><b>Booster Sensitivity Test:</b>                  Condition                  Tetryl, gm                  Wax, in. for 50% Detonation                  Wax, gm                  Density, gm/cc</p>	<p><b>Decomposition Equation:</b>                  Oxygen, atoms/sec                  (Z/sec)                  Heat, kilocalorie/mole                  (ΔH kcal/mol)                  Temperature Range, °C                  Phase</p>										
<p><b>Heat of:</b>                  Combustion, cal/gm                      2209                  Explosion, cal/gm                         725                      Gas Volume, cc/gm                    604                  Formation, cal/gm                  Fusion, cal/gm</p>	<p><b>Armor Plate Impact Test:</b></p> <p><b>40 mm Mortar Projectile:</b>                  50% Inert, Velocity, ft/sec                  Aluminum Fineness</p> <p><b>500-lb General Purpose Bombs:</b>                  Plate Thickness, inches</p> <p>1                  1¼                  1½                  1¾</p>										
<p><b>Specific Heat; cal/gm/°C    (b)</b></p> <table border="0"> <tr> <td style="text-align: center;">°C</td> <td></td> </tr> <tr> <td style="text-align: center;">-50</td> <td style="text-align: center;">0.217</td> </tr> <tr> <td style="text-align: center;">0</td> <td style="text-align: center;">0.217</td> </tr> <tr> <td style="text-align: center;">25</td> <td style="text-align: center;">0.217</td> </tr> <tr> <td style="text-align: center;">50</td> <td style="text-align: center;">0.217</td> </tr> </table>	°C		-50	0.217	0	0.217	25	0.217	50	0.217	<p><b>Bomb Drop Test:</b></p> <p><b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>                  Max Safe Drop, ft</p> <p><b>500-lb General Purpose Bomb vs Concrete:</b>                  Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p> <p><b>1000-lb General Purpose Bomb vs Concrete:</b>                  Height, ft                  Trials                  Unaffected                  Low Order                  High Order</p>
°C											
-50	0.217										
0	0.217										
25	0.217										
50	0.217										
<p><b>Burning Rate:</b>                  cm/sec</p>											
<p><b>Thermal Conductivity:</b>                  cal/sec/cm/°C</p>											
<p><b>Coefficient of Expansion;</b>                  Linear, %/°C                  Volume, %/°C</p>											
<p><b>Hardness, Mohs' Scale:</b></p>											
<p><b>Young's Modulus:</b>                  E', dynes/cm<sup>2</sup>                  E, lb/inch<sup>2</sup>                  Density, gm/cc</p>											
<p><b>Compressive Strength: lb/inch<sup>2</sup></b></p>											
<p><b>Vapor Pressure:</b>                  °C                      mm Mercury</p>											

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																								
		Glass Cones	Steel Cones																													
	Hole Volume																															
	Hole Depth																															
	<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Color:</b> Orange to brown</p>																														
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Principal Uses:</b> Primary explosive</p>																															
	<p><b>Method of Loading:</b> Pressed</p>																															
	<p><b>Loading Density: gm/cc</b>      <b>psi x 10<sup>5</sup></b></p> <table> <tr> <td>10</td> <td>20</td> <td>30</td> <td>40</td> <td>80</td> </tr> <tr> <td>1.63</td> <td>1.77</td> <td>1.81</td> <td>1.86</td> <td>1.98</td> </tr> </table>	10	20	30	40	80	1.63	1.77	1.81	1.86	1.98																					
10	20	30	40	80																												
1.63	1.77	1.81	1.86	1.98																												
	<p><b>Storage:</b></p> <p>Method: Wet</p> <p>Hazard Class (Quantity-Distance): Class 9</p> <p>Compatibility Group: Group M (wet)</p> <p>Exudation:</p>																															
	<p><u>Solubility in Water,</u> <u>gm/100 gm solvent, at:</u></p> <p>30°C: 0.245</p>																															
	<p><u>Stab Sensitivity:</u></p> <table> <thead> <tr> <th rowspan="2"><u>Density</u> <u>gm/cc</u></th> <th colspan="3"><u>Firing Point (inch-ounces)</u></th> </tr> <tr> <th><u>0%</u></th> <th><u>50%</u></th> <th><u>100%</u></th> </tr> </thead> <tbody> <tr> <td>1.63</td> <td>73</td> <td>79</td> <td>84</td> </tr> <tr> <td>1.77</td> <td>66</td> <td>75</td> <td>83</td> </tr> <tr> <td>1.81</td> <td>42</td> <td>48</td> <td>64</td> </tr> <tr> <td>1.86</td> <td>12</td> <td>15</td> <td>18</td> </tr> <tr> <td>1.93</td> <td>11</td> <td>17</td> <td>21</td> </tr> <tr> <td>1.98</td> <td>7</td> <td>11</td> <td>14</td> </tr> </tbody> </table>	<u>Density</u> <u>gm/cc</u>	<u>Firing Point (inch-ounces)</u>			<u>0%</u>	<u>50%</u>	<u>100%</u>	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
<u>Density</u> <u>gm/cc</u>	<u>Firing Point (inch-ounces)</u>																															
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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																													
	<p><u>Activation Energy:</u></p> <p>kcal/mol: 82.6</p> <p>Induction Period, sec: 0.5-10</p>																															



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: <sup>64</sup>

(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:

<u>2</u>	<u>3</u>	<u>6</u>	<u>9</u>
2122	2093	2146	2179

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<sup>64</sup>See footnote 1, page 10.

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>            Density, gm/cc 1.64            Charge Wt, lb 2.180</p> <p><b>Total No. of Fragments:</b>            For TNT 703            For Subject HE 999</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>            Density, gm/cc 1.63            Charge Wt, lb 0.864</p> <p><b>Total No. of Fragments:</b>            For TNT 514            For Subject HE 685</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth													
	Glass Cones	Steel Cones																			
Hole Volume																					
Hole Depth																					
<p><b>Fragment Velocity: ft/sec</b>            At 9 ft 2690            At 25½ ft 2460            Density, gm/cc 1.64</p>	<p><b>Color:</b></p> <p><b>Principal Uses:</b> Land mines and demolition charges</p>																				
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> (d)            Peak Pressure 111            Impulse 109            Energy --</p> <p><b>Air, Confined:</b>            Impulse</p> <p><b>Under Water:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Underground:</b>            Peak Pressure            Impulse            Energy</p>	<p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density: gm/cc</b> 1.68</p>																				
<p><b>Booster Sensitivity Test:</b> (c)</p> <table border="0"> <tr> <td>Condition</td> <td>Pressed</td> <td>Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>100</td> <td>100</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td>1.94</td> <td>1.82</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.61</td> <td>1.68</td> </tr> </table>	Condition	Pressed	Cast	Tetryl, gm	100	100	Wax, in. for 50% Detonation	1.94	1.82	Density, gm/cc	1.61	1.68	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>Exudes at 65°C</td> </tr> </table> <p><b>Preparation:</b></p> <p>The ternary explosive system consisting of RDX, tetryl and TNT is prepared by adding the appropriate weight of water-wet RDX to a tetryl (40/60) previously melted in a steam-jacketed melt kettle. Heating and stirring are continued until all the water is evaporated and the mixture is uniform in composition. PTX-1 is also prepared by adding tetryl to RDX Composition B.</p> <p><b>Compatibility with Metals:</b></p> <p><u>Dry:</u> Aluminum, mild steel not affected.</p> <p><u>Wet:</u> Aluminum, mild steel not affected.</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	Exudes at 65°C
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Exudation	Exudes at 65°C																				

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: <sup>65</sup>

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

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

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

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

(e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

<u>0</u>	<u>2</u>	<u>3</u>	<u>6</u>	<u>7</u>	<u>9</u>
153C	1402	1623	1466 1506	1437	1379 1429 1469

<sup>65</sup>See footnote 1, page 10.



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.68                  Charge Wt, lb 2.226</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 1128</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.70                  Charge Wt, lb 0.897</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 750</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td colspan="2">~ 130</td> </tr> <tr> <td>Hole Depth</td> <td colspan="2"></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume	~ 130		Hole Depth													
	Glass Cones	Steel Cones																			
Hole Volume	~ 130																				
Hole Depth																					
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft 3020                  At 25½ ft 2850                  Density, gm/cc 1.70</p>	<p><b>Color:</b></p> <p><b>Principal Uses:</b> Shaped charges                  Fragmentation charges</p>																				
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> (d)                  Peak Pressure 113                  Impulse 113                  Energy --</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density: gm/cc</b> 1.70</p>																				
<p><b>Booster Sensitivity Test:</b> (j)</p> <table border="0"> <tr> <td>Condition</td> <td>Pressed</td> <td>Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>100</td> <td>100</td> </tr> <tr> <td>Wax in. for 50% Detonation</td> <td>1.87</td> <td>2.32</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.70</td> <td>1.61</td> </tr> </table>	Condition	Pressed	Cast	Tetryl, gm	100	100	Wax in. for 50% Detonation	1.87	2.32	Density, gm/cc	1.70	1.61	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>None at 65°C</td> </tr> </table> <p><b>Preparation:</b>                  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.</p> <p><b>Compatibility with Metals:</b></p> <p><u>Dry:</u> Aluminum, mild steel not affected.  <u>Wet:</u> Aluminum not affected.</p>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group I	Exudation	None at 65°C
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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:

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>8</u>	<u>9</u>
1530	1482	1483 1623	1414	1445	1466	1838	1379 1429 1469

<sup>66</sup>See footnote 1, page 10.

Composition: %		Molecular Weight:	217
RDX	90	Oxygen Balance:	
Polyvinyl Acetate	8	CO <sub>2</sub> %	-37
Dibutylphthalate	2	CO %	-10
		Density: gm/cc	Pressed 1.60
		Melting Point: °C	
C/H Ratio		Softening Point: °C	92
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm Sample Wt 20 mg	39	Refractive Index, n <sub>20</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in. Sample Wt, mg	9 13	n <sub>25</sub> <sup>D</sup>	
		n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe	Crackles	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	0.45
Rifle Bullet Impact Test: 5 Trials *		120°C	0.88
Explosions	20	135°C	--
Portals	0	150°C	11+
Burned	60		
Unaffected	20	200 Gram Bomb Sand Test:	
*100 trials at -46°C - Unaffected		Sand, gm	58.5
Explosion Temperature: °C		<b>Sensitivity to Initiation:</b>	
Seconds, 0.1 (no cap used)	--	Minimum Detonating Charge, gm	
1	330	Mercury Fulminate	
5 Decomposes	375	Lead Azide	0.22
10	265	Tetryl	
15			
20		Ballistic Mortar, % TNT:	
75°C International Heat Test:		Trautl Test, % TNT:	
% Loss in 48 Hrs		Plate Dent Test:	
		Method	
100°C Heat Test:		Condition	
% Loss, 1st 48 Hrs	0.10	Confined	
% Loss, 2nd 48 Hrs	0.06	Density, gm/cc	
Explosion in 100 Hrs	None	Brisance, % TNT	
Flammability Index:		Detonation Rate:	
		Confinement	None
Hygroscopicity: % 30°C, 90% RH	0.20	Condition	Cast
		Charge Diameter, in.	1.0
Volatility: 55°C, vacuo, 6 hrs	0.03	Density, gm/cc	1.60
		Rate, meters/second	7910





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: <sup>67</sup>

- (a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

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<sup>67</sup>See footnote 1, page 10.

<b>Composition:</b> % C 27 3.4 15.6 $(H_2C-CH-ONO_2)_n$ O 54 C/H Ratio 0.203	<b>Molecular Weight:</b> $(C_2H_3NO_3)_n$ (89) <sub>n</sub>	
	<b>Oxygen Balance:</b> CO, % -45 CO % -9	
	<b>Density:</b> gm/cc	
	<b>Melting Point:</b> °C (Soft Pb) 50	
	<b>Freezing Point:</b> °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> 14.86%N Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 4 Sample Wt, mg	<b>Boiling Point:</b> °C	
	<b>Refractive Index, n<sub>D</sub><sup>20</sup></b> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>	
	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C 100°C 16 hours 11+ 120°C 16 hours 11+ 135°C 150°C	
<b>Friction Pendulum Test:</b> Steel Shoe Crackles Fiber Shoe Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 49.9	
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partial Burned Unaffected	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide Tetryl	
	<b>Ballistic Mortar, % TNT:</b>	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 265 10 15 20	<b>Treuzl Test, % TNT:</b>	
	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 1.9 % Loss, 2nd 48 Hrs 2.1 Explosion in 100 Hrs None		
<b>Flammability Index:</b>		
<b>Hygroscopicity:</b> % 30°C, 90% RH 0.62		
<b>Volatility:</b>		

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb  <b>Total No. of Fragments:</b> For TNT For Subject HE	<b>Shaped Charge Effectiveness, TNT = 100:</b>  <table style="width: 100%; border: none;"> <tr> <td style="width: 60%;"></td> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth									
		Glass Cones	Steel Cones														
Hole Volume																	
Hole Depth																	
	<b>Color:</b>  <b>Principal Uses:</b>  <b>Method of Loading:</b>  <b>Loading Density: gm/cc</b>																
<b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc	<b>Storage:</b>  Method  Hazard Class (Quantity-Distance)  Compatibility Group  Exudation																
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy	<b>55.5°C KI Test:</b>  <table style="width: 100%; border: none;"> <tr> <td>Minutes</td> <td style="text-align: right;">60+</td> </tr> </table> <b>34.5°C Heat Test:</b>  <table style="width: 100%; border: none;"> <tr> <td>Salmon Pink</td> <td style="text-align: right;"><u>Minutes</u> 20</td> </tr> <tr> <td>Red Fumes</td> <td style="text-align: right;">25</td> </tr> <tr> <td>Explodes</td> <td style="text-align: right;">300+</td> </tr> </table> <b>40-Hour Hydrolysis Test:</b>  <table style="width: 100%; border: none;"> <tr> <td>% HNO<sub>3</sub></td> <td style="text-align: right;">5.07</td> </tr> </table> <b>Heat of:</b>  <table style="width: 100%; border: none;"> <tr> <td>Combustion, cal/gm</td> <td style="text-align: right;">2960</td> </tr> <tr> <td>Explosion, cal/gm</td> <td style="text-align: right;">900</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td style="text-align: right;">838</td> </tr> </table>	Minutes	60+	Salmon Pink	<u>Minutes</u> 20	Red Fumes	25	Explodes	300+	% HNO <sub>3</sub>	5.07	Combustion, cal/gm	2960	Explosion, cal/gm	900	Gas Volume, cc/gm	838
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Explodes	300+																
% HNO <sub>3</sub>	5.07																
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  $-5^{\circ}\text{C}$  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  $20^{\circ}\text{C}$ .

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  $50^{\circ}\text{C}$ . (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	Molecular Weight:	230
	Oxygen Balance:	
	CO, %	-70
	CO %	-35
	Density: gm/cc	Hand tamped 1.37
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 53 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 13 Sample Wt, mg 25	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$	
	$n_{30}^D$	
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test:	
	cc/40 Hrs, at	
	90°C	--
	100°C	0.34
	120°C	0.56
	135°C	
	150°C	
Rifle Bullet Impact test: Trials  Explosions 0 Portia 0 Burned 0 Unaffected 100	200 Gram Bomb Sand Test:	
	Sand, gm	40.1
	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	Sensitivity to Initiation:	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	
	Lead Azide	0.20
	Tetryl	
	Ballistic Mortar, % TNT: (a)	118
	Traurl Test, % TNT:	
	Plate Dent test: (b)	
	Method	B
	Condition	Hand tamped
	Confined	Nb
	Density, gm/cc	1.37
	Brisance, % TNT	85
100°C Heat Test: % Loss, 1st 48 Hrs 0.03 % Loss, 2nd 48 Hrs 0.04 Explosion in 100 Hrs None	Detonation Rate:	
	Confinement	None
Flammability Index:  Hygroscopicity: % 30°C, 90% RH 0.04	Condition	Hand tamped
	Charge Diameter, in.	1.0
Volatility:	Density, gm/cc	1.37
	Rate, meters/second	7390

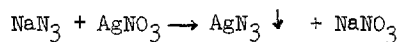
<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b></p> <p>Density, gm/cc 1.36 Charge Wt, lb 1.766</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT 703 For Subject HE 592</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <p>Density, gm/cc 1.42 Charge Wt, lb 0.756</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT 514 For Subject HE 501</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> White</p> <p><b>Principol Uses:</b> Plastic demolition explosive</p> <p><b>Method of Loading:</b> Hand tamped</p> <p><b>Loading Density: gm/cc</b> 1.37</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b></p> <p>At 9 ft 2650 At 25½ ft 2370</p> <p>Density, gm/cc 1.395</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation None at 85°C in 30 hrs None at 95°C in 48 hrs Exudes at 105°C in 48 hrs</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b></p> <p>Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b></p> <p>Impulse</p> <p><b>Under Water:</b></p> <p>Peak Pressure Impulse Energy</p> <p><b>Underground:</b></p> <p>Peak Pressure Impulse Energy</p> <p><u>Preparation:</u></p> <p>RIPE is manufactured by simple mechanical mixing of RDX in oil.</p>	<p><u>Origin:</u></p> <p>RIPE, a mechanical mixture of RDX and Gulf Crown E Oil, was developed in the United States during World War II.</p> <p><u>References:</u><sup>68</sup></p> <p>(a) L. C. Smith and E. G. Eyster, <u>Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests</u>, OSRD Report No. 5746, 27 December 1945.</p> <p>(b) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.</p> <p>(c) Also see the following Picatinny Arsenal Technical Reports on RIPE: 1713, 1695 and 1517.</p>									

<sup>68</sup>See footnote 1, page 10.

Composition: % N 28.0 Ag 72.0 Ag-N=N≡N C/H Ratio	Molecular Weight: (AgN <sub>2</sub> )	150
	Oxygen Balance: CO <sub>2</sub> % CO %	-5 -5
	Density: gm/cc	Crystal 5.1
	Melting Point: °C (a)	251 <del>Decomposes rapidly above melting point to</del> silver and nitrogen.
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
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 % Portions 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	
75°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT:	
	Trauzl Test, % Hg(ONC) <sub>2</sub> (c)	aa
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT	
	Flammability Index:	
Hygroscopicity: % (b) 25°C, 100% RH	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	0.04
Volatility: 75°C, 24 hrs		0.00



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <p><b>Color:</b> White to gray</p> <p><b>Principal Uses:</b> Initiators</p> <p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density:</b> gm/cc Variable</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																			
	Glass Cones	Steel Cones																									
Hole Volume																											
Hole Depth																											
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M</td> </tr> <tr> <td>Exudation</td> <td>None</td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M	Exudation	None																		
Method	Wet																										
Hazard Class (Quantity-Distance)	Class 9																										
Compatibility Group	Group M																										
Exudation	None																										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p> <p><b>Explosive Power:</b> (f)</p> <table border="0"> <tr> <td>Kilogram meters</td> <td>192,000</td> </tr> <tr> <td>% Mercury Fulminate</td> <td>1.097</td> </tr> </table>	Kilogram meters	192,000	% Mercury Fulminate	1.097	<p><b>Initiating Efficiency:</b></p> <table border="0"> <tr> <td>Grams Required to Give Complete Initiation of TNT</td> <td>(c) 0.02-0.05</td> </tr> </table> <p><b>Solubility in 100 gm Solvent at Room Temperature:</b></p> <table border="0"> <thead> <tr> <th><u>Solvent</u></th> <th><u>Grams</u></th> </tr> </thead> <tbody> <tr> <td>Water (b)</td> <td>0.006</td> </tr> <tr> <td>Ammonium hydroxide</td> <td>Soluble</td> </tr> <tr> <td>Nitric acid</td> <td>Decomposes</td> </tr> <tr> <td>Ether (b)</td> <td>0.017</td> </tr> <tr> <td>Ethyl alcohol, 95%</td> <td>0.006</td> </tr> <tr> <td>Acetone</td> <td>0.015</td> </tr> <tr> <td>Unaffected by water and CO<sub>2</sub>.</td> <td>(d)</td> </tr> </tbody> </table> <p><b>Heat of:</b></p> <table border="0"> <tr> <td><b>Explosion, cal/gm</b> (c, d)</td> <td><b>452</b></td> </tr> <tr> <td><b>Formation, cal/gm</b> (e)</td> <td><b>67.8</b></td> </tr> </table>	Grams Required to Give Complete Initiation of TNT	(c) 0.02-0.05	<u>Solvent</u>	<u>Grams</u>	Water (b)	0.006	Ammonium hydroxide	Soluble	Nitric acid	Decomposes	Ether (b)	0.017	Ethyl alcohol, 95%	0.006	Acetone	0.015	Unaffected by water and CO <sub>2</sub> .	(d)	<b>Explosion, cal/gm</b> (c, d)	<b>452</b>	<b>Formation, cal/gm</b> (e)	<b>67.8</b>
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<b>Explosion, cal/gm</b> (c, d)	<b>452</b>																										
<b>Formation, cal/gm</b> (e)	<b>67.8</b>																										

Preparation:

Prepare the following aqueous solutions:

- a. 5%  $\text{NaN}_3$ , sodium azide, 50 cc
- b. 25%  $\text{AgNO}_3$ , silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium azide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is fastened to the stopcock of the separatory funnel so that the funnel can be emptied by remote control. The silver nitrate solution is now stirred very rapidly and the sodium azide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and washed free of sodium azide and silver nitrate with distilled water.

Silver azide should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver azide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver azide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver azide (Ref g). White silver azide is less affected by light than mercury or lead azide (Ref h). Long colorless crystals which explode on breaking are obtained from ammonium hydroxide.

Origin:

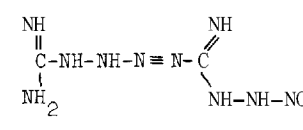
Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid ( $\text{HN}_3$ ) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "colloidal" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925)). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref i).

References:<sup>69</sup>

- (a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).
- (b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).
- (c) E. De W. S. Colver, High Explosives, London and New York, p. 527.
- (d) A. Stettbacher, Spreng u. 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).

<sup>69</sup>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.

Composition: %  C 12.8 H 4.3 N 74.4 O 8.5  C/H Ratio 0.068  	Molecular Weight: (C <sub>2</sub> H <sub>3</sub> N <sub>10</sub> O)	188
	Oxygen Balance:	
	CO <sub>2</sub> %	-60
	CO %	-43
	Density: gm/cc At 3000 psi	1.05
Melting Point: °C	Explodes	140-160
Freezing Point: °C		
Boiling Point: °C		
Impact Sensitivity, 2 Kg Wt:		
Bureau of Mines Apparatus, cm	7	
Sample Wt 20 mg		
Picatinny Arsenal Apparatus, in.2; (8 oz wt)	8	
Sample Wt, mg		
Refractive Index, n <sub>D</sub> <sup>20</sup>		
n <sub>D</sub> <sup>25</sup>		
n <sub>D</sub> <sup>30</sup>		
Friction Pendulum Test:		
Steel Shoe		
Fiber Shoe		
Rifle Bullet Impact Test: Trials		
Explosions %		
Partials		
Burned		
Unaffected		
Vacuum Stability Test:		
cc/40 Hrs, at		
90°C		
100°C		
120°C		
135°C		
150°C		
200 Gram Bomb Sand Test:		
Sand gm		28.0
Black powder fuse	4.0	
Explosion Temperature: °C		
Seconds, 0.1 (no cap used)		
1		
5	160	
10		
15		
20		
Sensitivity to Initiation:		
Minimum Detonating Charge, gm		
Mercury Fulminate		0.40
Lead Azide		
Tetryl		
Ballistic Mortar, % TNT:		
Trauzl Test, % TNT: (a)		61
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:		
Detonation Rate:		
Confinement		
Condition		
Charge Diameter, in.		
Density, gm/cc		
Rate, meters/second		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p><b>Color:</b> Pale yellow</p> <hr/> <p><b>Principal Uses:</b> Priming compositions and detonators</p> <hr/> <p><b>Method of Loading:</b> Pressed</p> <hr/> <p><b>Loading Density: gm/cc</b> At 3000 psi 1.05</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="0"> <tr> <td>Method</td> <td>Wet</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td>Group M</td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Wet	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group	Group M	Exudation		
Method	Wet									
Hazard Class (Quantity-Distance)	Class 9									
Compatibility Group	Group M									
Exudation										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Solubility:</b> Practically insoluble in water, alcohol, acetone, ether, benzene, carbontetrachloride or ethylenedichloride.</p> <p><b>Sensitivity to Electrostatic Discharge, Joules:</b> (b)</p> <table border="0"> <tr> <td>Unconfined</td> <td>0.010</td> </tr> <tr> <td>Confined</td> <td>0.012</td> </tr> </table> <p><b>Heat of:</b></p> <table border="0"> <tr> <td>Explosion, cal/gm</td> <td>658</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>1190</td> </tr> </table> <p><b>Initiating Efficiency:</b> Tetracene is not efficient in initiating high explosives.</p>	Unconfined	0.010	Confined	0.012	Explosion, cal/gm	658	Gas Volume, cc/gm	1190	
Unconfined	0.010									
Confined	0.012									
Explosion, cal/gm	658									
Gas Volume, cc/gm	1190									

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:<sup>70</sup>

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

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

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

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

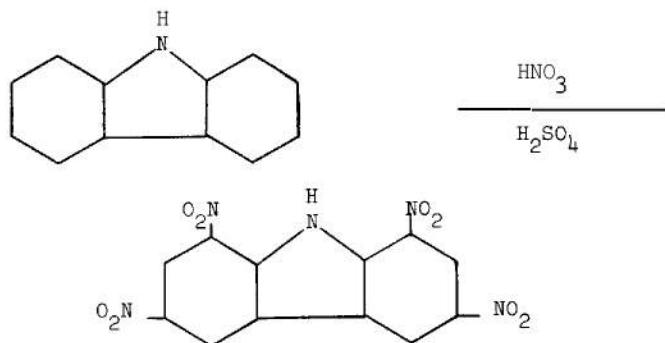
<u>0</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>7</u>	<u>8</u>	<u>9</u>
1450	11	453	1104	407	318	859
			2164			2179

<sup>70</sup>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 <sub>12</sub> H <sub>5</sub> N <sub>5</sub> O <sub>8</sub> ) 347 Oxygen Balance: CO, % -85 CO % -30 Density: gm/cc Melting Point: °C Pure 1,3,6,8-isomer 296 Freezing Point: °C Boiling Point: °C Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 18 Sample Wt, mg 14	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	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate -- Lead Azide 0.20 Tetryl 0.25
Explosion Temperature: °C Seconds, 0.1 (no cap used) -- 1 -- 5 Decomposes 470 10 15 20	Ballistic Mortar, % TNT: Trauzl Test, % TNT:	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
75°C International Heat Test: % Loss in 48 Hrs	Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
100°C Heat Test: % Loss, 1st 48 Hrs 0.15 % Loss, 2nd 48 Hrs 0.05 Explosion in 100 Hrs None		
Flammability Index:		
Hygroscopicity: % 30°C, 90% RH 0.01		
Volatility:		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth								
		Glass Cones	Steel Cones													
	Hole Volume															
	Hole Depth															
	<p><b>Color:</b></p> <p>Light yellow</p>															
<p><b>Principal Uses:</b> Component of igniter and pyrotechnic compositions</p>																
<p><b>Method of Loading:</b></p> <p>Pressed</p>																
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Loading Density:</b> gm/cc</p>															
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Storage:</b></p> <table> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 9</td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 9	Compatibility Group		Exudation								
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	Hazard Class (Quantity-Distance)	Class 9														
	Compatibility Group															
	Exudation															
<p><b>Solubility in Water, gm/100 gm (%), at:</b></p> <table> <tr> <td>95°C</td> <td>0.10</td> </tr> </table>	95°C	0.10														
95°C	0.10															
<p><b>Qualitative Solubilities:</b></p> <table> <thead> <tr> <th><u>Solvent</u></th> <th><u>Solubility</u></th> </tr> </thead> <tbody> <tr> <td>Nitrobenzene</td> <td>Very soluble</td> </tr> <tr> <td>Acetone</td> <td>Soluble</td> </tr> <tr> <td>Benzene</td> <td>Insoluble</td> </tr> <tr> <td>Chloroform</td> <td>Insoluble</td> </tr> <tr> <td>Carbontetrachloride</td> <td>Insoluble</td> </tr> <tr> <td>Ether</td> <td>Insoluble</td> </tr> <tr> <td>Ether, petroleum</td> <td>Insoluble</td> </tr> </tbody> </table>	<u>Solvent</u>	<u>Solubility</u>	Nitrobenzene	Very soluble	Acetone	Soluble	Benzene	Insoluble	Chloroform	Insoluble	Carbontetrachloride	Insoluble	Ether	Insoluble	Ether, petroleum	Insoluble
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Ether, petroleum	Insoluble															



Preparation:

Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of  $\text{H}_2\text{SO}_4$  (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at  $25^\circ\text{--}35^\circ\text{C}$ . After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to  $80^\circ\text{--}85^\circ\text{C}$  and maintaining this temperature for one hour. The sulphate is now cooled to  $20^\circ\text{C}$ .

Nitration: The sulfonate solution is slowly added to 168 gms of  $\text{HNO}_3$  (Plant grade specific gravity 1.525 at  $15^\circ\text{C}$ ) maintaining the temperature at  $30^\circ$  to  $50^\circ\text{C}$ . (Time required - 1 hour 25 minutes). The temperature is then gradually raised to  $70^\circ$  to  $75^\circ\text{C}$  and maintained for one hour after which the temperature is raised to  $85^\circ$  to  $90^\circ\text{C}$  and held for one hour, then lowered to room temperature before drowing.

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 ( $95^\circ$  to  $100^\circ\text{C}$ ) 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  $100^\circ$  to  $110^\circ\text{C}$  for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared:  $280^\circ\text{C}$  (compares to  $296^\circ\text{C}$  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:<sup>71</sup>

(a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbazole," J Am Chem Soc, 75, 4289-4291 (1953).

(b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136,330, 11 April 1951.

(c) D. B. Murphy et al, Long Range Basic Technical Research Leading to the Development of Improved Ignition Type Powders - The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.

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

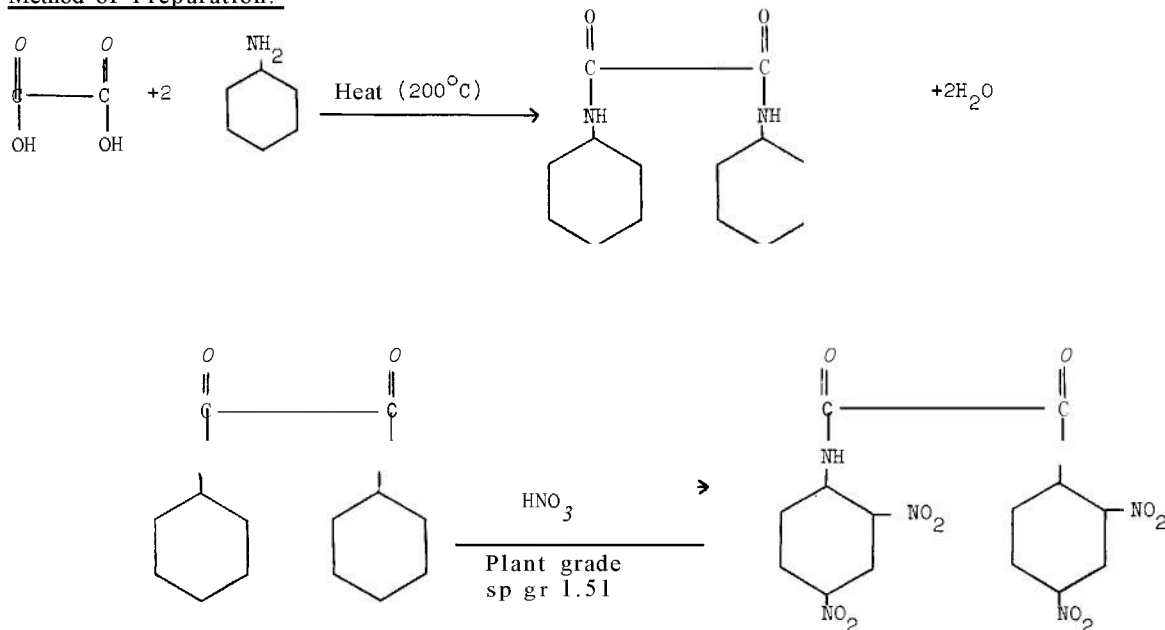
(e) Also see the following Picatinny Arsenal Technical Reports on Tetranitrocarbazole:

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>7</u>
2180	1802	1973	1984	1647 1937

<sup>71</sup>See footnote 1, page 10.

<b>Composition:</b> % C 40.0 H 1.9 N 20.0 O 38.1 C/H Ratio 0.735		<b>Molecular Weight:</b> (C <sub>14</sub> H <sub>8</sub> N <sub>6</sub> O <sub>10</sub> ) 420 <b>Oxygen Balance:</b> CO, % -84 CO % -31 <b>Density:</b> gm/cc <b>Melting Point:</b> °C Decomposes 313 <b>Freezing Point:</b> °C
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm -- Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 30 Sample Wt, mg 11	<b>Boiling Point:</b> °C <b>Refractive Index, n<sub>D</sub><sup>20</sup></b> <b>n<sub>D</sub><sup>25</sup></b> <b>n<sub>D</sub><sup>30</sup></b>	
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C -- 100°C -- 120°C 0.11 135°C 150°C	
<b>Rifle Bullet Impact Test:</b> Trials Explosions % Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 16.3	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) -- 1 -- 5 392 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate Lead Azide 0.20 Tetryl 0.25	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b> <b>Trauzl Test, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs 0.07 % Loss, 2nd 48 Hrs 0.00 Explosion in 100 Hrs None	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
<b>Flammability Index:</b>	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second	
<b>Hygroscopicity:</b> % 30°C, 90% RH Trace		
<b>Volatility:</b>		

<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p>																				
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Principal Uses:</b> Component of black powder type and pyrotechnic compositions</p>																				
	<p><b>Method of Loading:</b> Pressed and extruded compositions</p>																				
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Loading Density: gm/cc</b></p>																				
	<p><b>Storage:</b></p> <p>Method: Dry</p> <p>Hazard Class (Quantity-Distance): Class 9</p> <p>Compatibility Group</p> <p>Exudation</p>																				
	<p><b>Solubility, gm/100 cc Solvent, in:</b></p> <table border="1"> <thead> <tr> <th></th> <th><u>°C</u></th> <th><u>g</u></th> </tr> </thead> <tbody> <tr> <td>Water</td> <td>100</td> <td>&lt;0.10</td> </tr> <tr> <td>Nitrobenzene</td> <td>150</td> <td>715</td> </tr> </tbody> </table>		<u>°C</u>	<u>g</u>	Water	100	<0.10	Nitrobenzene	150	715											
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Nitric acid	Soluble																				
Caustic potash	Soluble																				
Dimethyl formamide	Very soluble																				

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 Buchner 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 97.546 of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892).

References: <sup>72</sup>

- (a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF 1-88, 20 December 1954.

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<sup>72</sup>See footnote 1, page 10.

Composition: %			Molecular Weight: (C <sub>7</sub> H <sub>5</sub> N <sub>5</sub> O <sub>8</sub> )	287	
C	29.3		<b>Oxygen Balance:</b>		
H	1.7		CO <sub>2</sub> %	-47	
N	24.4		CO %	- 8	
O	44.6		Density: gm/cc	Crystal	1.73
C/H Ratio	0,420		Melting Point: °C		130
			Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C		
Bureau of Mines Apparatus, cm	26		Refractive Index, n <sub>20</sub> <sup>D</sup>		
Sample Wt 20 mg			n <sub>25</sub> <sup>D</sup>		
Picatinny Arsenal Apparatus, in.	8		n <sub>30</sub> <sup>D</sup>		
Sample Wt, mg	18				
Friction Pendulum Test:					
Steel Shoe	Crackles			--	
Fiber Shoe	Unaffected			0.3	
Rifle Bullet Impact Test:	Trials		120°C	1.0	
	%		135°C	--	
Explosions	13		150°C	11+	
Partials	54				
Burned	10		200 Gram Bomb Sand Test:		
Unaffected	23		Sand, gm	54.2	
Explosion Temperature: °C			Sensitivity to Initiation;		
Seconds, 0.1 (no cap used)	340		Minimum Detonating Charge, gm		
1	314		Mercury Fulminate	0.20*	
5 Ignites	257		Lead Azide	0.10*	
10	238		*Alternative initiating charges.		
15	236		Ballistic Mortar, % TNT: (a)	130	
20	234		Troul Test, % TNT: (b)	125	
75°C International Heat Test:			Plate Dent Test: (c)		
% Loss in 48 Hrs	0.01		Method	A B	
100°C Heat Test:			Condition	Pressed Pressed	
% Loss, 1st 48 Hrs	0.1		Confined	Yes No	
% Loss, 2nd 48 Hrs	0.0		Density, gm/cc	1.50 1.59 1.36	
Explosion in 100 Hrs	None		Brisance, % TNT	116 115 96	
Flammability Index:	244		Detonation Rate:		
Hygroscopicity: % 30°C, 90% RH	0.04		Confinement	None	
Volatility: 25°C	0.00		Condition	Pressed	
			Charge Diameter, in.	1.0	
			Density, gm/cc	1.71	
			Rate, meters/second	7850	

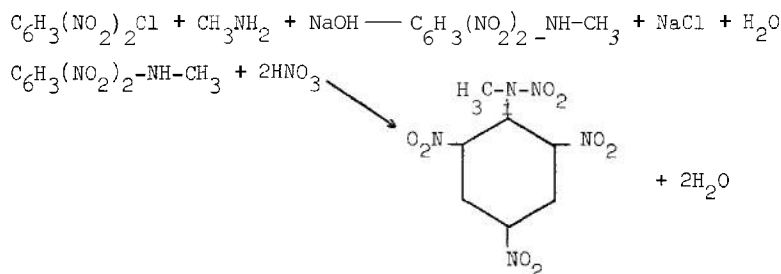
Booster Sensitivity test: (d) Tetryl, gm 100 Wax, in. for 50% Detonation 2.01 Wax, gm Density, gm/cc 1.58	Decomposition Equation: (g) (h) $10^{15.4}$ $10^{12.9}$ (Z/sec) Heat, kilocalorie/mole 38.4 34.9 (AH, kcal/mol) Temperature Range, °C 211-260 132-164 Phase Liquid Liquid
Heat of: Combustion, cal/gm 2925 Explosion, cal/gm 1080-1130 Gas Volume, cc/gm 760 Formation, cal/gm -14 Fusion, cal/gm (e) 22.2 Temperature, °C 127	Armor Plate Impact Test:  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness  500-lb General Purpose Bombs:  Plate Thickness, inches  1 1¼ 1½ 1¾
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	Bomb Drop Test:  T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:  Max Safe Drop, ft  500-lb General Purpose Bomb vs Concrete:  Height, ft Trials Unaffected Low Order High Order  1000-lb General Purpose Bomb vs Concrete:  Height, ft Trials Unaffected Low Order High Order
Thermal Conductivity: (f) cal/sec/cm/°C $5.81 \times 10^{-4}$ at 1.394 gm/cc $6.83 \times 10^{-4}$ at 1.528 gm/cc	
Coefficient of Expansion: Linear, %/°C  Volume, %/°C	
Hardness, Mohs' Scale:	
Young's Modulus: E, dynes/cm <sup>2</sup> E, lb/inch <sup>2</sup> Density, gm/cc	
Compressive Strength: lb/inch <sup>2</sup>	
Vapor Pressure: °C                      mm Mercury	



<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>            Density, gm/cc 1.58            Charge Wt, lb 2.052</p> <p><b>Total No. of Fragments:</b>            For TNT 703            For Subject HE 864</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>            Density, gm/cc 1.62            Charge Wt, lb 0.848</p> <p><b>Total No. of Fragments:</b>            For TNT 514            For Subject HE 605</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> Light yellow</p> <p><b>Principal Uses:</b> Boosters; ingredient of explosive mixtures, detonators, and blasting caps</p> <p><b>Method of Loading:</b> Pressed</p> <p><b>Loading Density: gm/cc</b> See below</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																																					
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<p><b>Fragment Velocity: ft/sec</b>            At 9 ft            At 25½ ft            Density, gm/cc</p>	<p><b>Storage:</b></p> <table border="1"> <tbody> <tr> <td>Method</td> <td>Dry</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td>Class 0</td> </tr> <tr> <td>Compatibility Group</td> <td>Group I</td> </tr> <tr> <td>Exudation</td> <td>Does not exude at 65°C</td> </tr> </tbody> </table>	Method	Dry	Hazard Class (Quantity-Distance)	Class 0	Compatibility Group	Group I	Exudation	Does not exude at 65°C																																				
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Hazard Class (Quantity-Distance)	Class 0																																												
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<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Air, Confined:</b>            Impulse</p> <p><b>Under Water:</b>            Peak Pressure            Impulse            Energy</p> <p><b>Underground:</b>            Peak Pressure            Impulse            Energy</p>	<p><b>Loading Density: gm/cc</b></p> <table border="1"> <thead> <tr> <th></th> <th colspan="2">Cast 1.62</th> <th colspan="2">Pressed</th> <th colspan="2">psi x 10<sup>3</sup></th> </tr> </thead> <tbody> <tr> <td>0</td> <td>3</td> <td>5</td> <td>10</td> <td>12</td> <td>15</td> <td>20</td> </tr> <tr> <td>0.9</td> <td>1.40</td> <td>1.47</td> <td>1.57</td> <td>1.60</td> <td>1.63</td> <td>1.67</td> </tr> <tr> <td></td> <td></td> <td></td> <td>30</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td>1.71</td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p><b>Effect of Temperature on Rate of Detonation:</b> (g)</p> <table border="1"> <tbody> <tr> <td>16 hrs at, °C</td> <td>-54</td> <td>21</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.52</td> <td>1.53</td> </tr> <tr> <td>Rate, m/sec</td> <td>7150</td> <td>7170</td> </tr> </tbody> </table>		Cast 1.62		Pressed		psi x 10 <sup>3</sup>		0	3	5	10	12	15	20	0.9	1.40	1.47	1.57	1.60	1.63	1.67				30							1.71				16 hrs at, °C	-54	21	Density, gm/cc	1.52	1.53	Rate, m/sec	7150	7170
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Preparation:

(Manufacture of Tetryl by Dinitromonomethylamine Process, Wannamaker Chemical Co., Inc.)



To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good agitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C).

The dinitromethylamine 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.

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

Unconfined	0.007
Confined	4.4

Solubility of tetryl, grams in 100 grams (%) of:

<u>Water</u>		<u>Carbon tetrachloride</u>		<u>Ether</u>		<u>95% Alcohol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.0050	0	0.007	0	0.188	0	0.320
20	0.0075	20	0.015	10	0.330	10	0.425
40	0.0110	40	0.058	20	0.418	20	0.563
80	0.0810	60	0.154	30	0.493	30	0.76
100	0.184					50	1.72
						75	5.33

<u>Chloroform</u>		<u>Carbon disulfide</u>		<u>Ethylene dichloride</u>		<u>Acetone</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.28	0	0.009	25	4.5	20	75
20	0.39	10	0.015	75	45	30	95
40	1.20	20	0.021			40	116
60	2.65	30	0.030			50	138

<u>Trichloroethylene</u>		<u>Ethyl acetate</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.07	20	~ 40	20	7.8	20	8.5
20	0.12			30	10.0		
40	0.26			40	12.5		
60	0.67			50	16.0		
80	1.50						
86	1.76						

<u>Xylene</u>		<u>TNT</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	3.3	80	82
30	4.4	100	149
40	5.4	120	645
50	6.0		

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part, by weight of sodium sulfite ( $\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$ ) in 4 parts water. The sulfite solution may be heated to 80°C to facilitate decomposition of the Tetryl.

References:<sup>73</sup>

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Ph Naoum, Z ges Schiess---Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
- (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.
- (e) C. A. Taylor and Wm H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Soc 45, (1923) p. 104.
- (f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.
- (g) R. J. Finkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).
- (i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PAIR No. 2383, November 1956.

(k) Also see the following Picatinny Arsenal Technical Reports on Tetryl:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
30	11	132	453	84	65	266	117	28	129
600	361	582	493	144	195	556	197	438	179
770	381	832	623	294	425	786	637	628	319
810	621	882	833	314	525	986	707	708	609
1180	861	1192	863	694	565	1086	807	788	709
1290	1041	1352	1113	774	625	1126	837	838	849
1350	1131	1372	1373	784	635	1316	857	1418	999
1360	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				

<sup>73</sup>See footnote 1, page 10.

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume                  Hole Depth</p>
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Light yellow to buff</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Bursters, demolition blocks</p>
	<p><b>Method of Loading:</b></p>
	<p><b>Loading Density:</b> gm/cc</p>
	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Exudes at 65°C</p>

Composition:		Molecular Weight:	270
%		Oxygen Balance:	
Tetryl	75	CO <sub>2</sub> %	-54
TNT	25	CO %	-12
		Density: gm/cc	Cast 1.59
		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 <sub>20</sub> <sup>D</sup>	
Sample Wt 20 mg		n <sub>25</sub> <sup>D</sup>	
Picatinny Arsenal Apparatus, in.	10	n <sub>30</sub> <sup>D</sup>	
Sample Wt, mg	17		
Friction Pendulum test:		Vacuum Stability test:	
Steel Shoe	Cracks	cc/40 Hrs, at	
Fiber Shoe	Unaffected	90°C	
		100°C	3.0
Rifle Bullet Impact test:	Trials	120°C	11+
	%	135°C	
Explosions	0	150°C	
Partials	30		
Burned	0	200 Gram Bomb Sand test:	
Unaffected	70	Sand, gm	53.7
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.23*
5 Ignites	310	Lead Azide	0.19*
10		Tetryl	
15		*Alternative initiating charges.	
20		Ballistic Mortar, % TNT: (a)	122
		Irauzl test, % TNT:	
75°C International Heat test:		Plate Dent Test: (b)	
% Loss in 48 Hrs		Method	B B
		Condition	Cast Cast
100°C Heat test:		Confined	No Yes
% Loss, 1st 48 Hrs		Density, gm/cc	1.66 1.62
% Loss, 2nd 48 Hrs		Brisance, % TNT	118 114
Explosion in 100 Hrs		Detonation Rate:	
Flammability Index: Will not continue to burn		Confinement	None
		Condition	Cast
Hygroscopicity: %	0.03	Charge Diameter, in.	1.0
		Density, gm/cc	1.60
Volatility:		Rate, meters/second	7385

<b>Fragmentation Test:</b>  <b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc 1.59 Charge Wt, lb 2.101  <b>Total No. of Fragments:</b> For TNT 703 For Subject HE 557  <b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc 1.60 Charge Wt, lb 0.845  <b>Total No. of Fragments:</b> For TNT 514 For Subject HE 591	<b>Shaped Charge Effectiveness, TNT = 100:</b>  <table style="width: 100%; border: none;"> <tr> <td style="text-align: center;">Glass Cones</td> <td style="text-align: center;">Steel Cones</td> <td style="text-align: right;">(d)</td> </tr> <tr> <td>Hole Volume</td> <td style="text-align: center;">127</td> <td></td> </tr> <tr> <td>Hole Depth</td> <td style="text-align: center;">120</td> <td></td> </tr> </table>	Glass Cones	Steel Cones	(d)	Hole Volume	127		Hole Depth	120	
	Glass Cones	Steel Cones	(d)							
	Hole Volume	127								
	Hole Depth	120								
	<b>Color:</b> Light yellow to buff									
<b>Principal Uses:</b> Burstlers, demolition blocks										
<b>Method of Loading:</b> Cast										
<b>Loading Density:</b> gm/cc 1.59										
<b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc	<b>Storage:</b>  Method Dry  Hazard Class (Quantity-Distance) Class 9  Compatibility Group Group I  Exudation Exudes at 65°C									
<b>Blast (Relative to TNT):</b>  <b>Air:</b> Peak Pressure Impulse Energy  <b>Air, Confined:</b> Impulse  <b>Under Water:</b> Peak Pressure Impulse Energy  <b>Underground:</b> Peak Pressure Impulse Energy	<b>Entectic Temperature, °C:</b> 67.5  <table style="width: 100%; border: none;"> <tr> <td style="text-align: center;">gn Tetryl/100 gn TNT</td> <td style="text-align: right;">54-82</td> </tr> <tr> <td style="text-align: center;">67.5°C</td> <td></td> </tr> </table> <b>Booster Sensitivity Test:</b> (c)  Condition Cast Tetryl, gn 100 Wax in. for 50% Detonation 1.66 Density, gm/cc 1.66	gn Tetryl/100 gn TNT	54-82	67.5°C						
gn Tetryl/100 gn TNT	54-82									
67.5°C										



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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.60                  Charge Wt, lb 2.090</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 840</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.60                  Charge Wt, lb 0.842</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 585</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p>Gloss Cones      Steel Cones</p> <p>Hole Volume</p> <p>Hole Depth</p>
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Light yellow to buff</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> Bursting, demolition blocks</p>
	<p><b>Method of Loading:</b> Cast</p>
	<p><b>Loading Density: gm/cc</b> 1.60</p>
	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) <b>Class 9</b></p> <p>Compatibility Group Group I</p> <p>Exudation Exudes at 65°C</p>

Composition: %  Tetryl 65  TNT 35  C/H Ratio	Molecular Weight:	264
	Oxygen Balance: CO <sub>2</sub> % CO %	-56 -14
	Density: gm/cc	1.60
	Melting Point: °C	68
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 Sample Wt, mg 17	Boiling Point: °C	
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 2.8 120°C 11+ 135°C 150°C	
Friction Pendulum Test: Steel Shoe Cracks Fiber Shoe Unaffected	200 Gram Bomb Sand Test: Sand, gm 52.6	
Rifle Bullet Impact Test: Trials Explosions 0 Partials 10 Burned 0 Unaffected 90	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate 0.23* Lead Azide 0.23* Tetryl *Alternative initiating charges.	
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 325 10 15 20	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 % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Detonation Rate: Confinement None Condition Cast	
Flammability Index: Will not continue to burn	Charge Diameter, in. 1.0 Density, gm/cc 1.60	
Hygroscopicity: % 0.02	Rate, meters/second 7310	
Volatility:		

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b></p> <p>Density, gm/cc                      1.61          Charge Wt, lb                        2.010</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT                                      703          For Subject HE                        856</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b></p> <p>Density, gm/cc                      1.60          Charge Wt, lb                        0.845</p> <p><b>Total No. of Fragments:</b></p> <p>For TNT                                      514          For Subject HE                        585</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>(d) Glass Cones</th> <th>(e) Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td>133</td> <td>126</td> </tr> <tr> <td>Hole Depth</td> <td>120</td> <td>119</td> </tr> </tbody> </table>		(d) Glass Cones	(e) Steel Cones	Hole Volume	133	126	Hole Depth	120	119
		(d) Glass Cones	(e) Steel Cones							
	Hole Volume	133	126							
	Hole Depth	120	119							
	<p><b>Color:</b>                                      Light yellow to buff</p>									
<p><b>Principal Uses:</b>    Bursting, demolition blocks</p>										
<p><b>Method of Loading:</b>                      Cast</p>										
<p><b>Fragment Velocity: ft/sec</b></p> <p>At 9 ft          At 25½ ft          Density, gm/cc</p>	<p><b>Loading Density: gm/cc</b>                      1.60</p>									
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b></p> <p>Peak Pressure          Impulse          Energy</p> <p><b>Air, Confined:</b></p> <p>Impulse</p> <p><b>Under Water:</b></p> <p>Peak Pressure          Impulse          Energy</p> <p><b>Underground:</b></p> <p>Peak Pressure          Impulse          Energy</p>	<p><b>Storage:</b></p> <p>Method    Dry</p> <p>Hazard Class (Quantity-Distance)              Class 9</p> <p>Compatibility Group                                      Group I</p> <p>Exudation    Exudes at 65°C</p>									

Tetrytol, 80/20, 75/25, 70/30, 65/35Compatibility with Metals:

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

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

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutectic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

References:<sup>74</sup>

(a) L. C. Smith and E. G. 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.

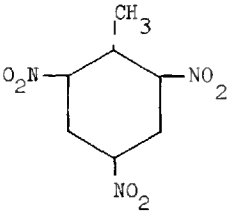
(d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.

(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:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1260	1291	1372	1193	1285	1376	1477	1158	1379
1360	1311		1213	1325	1436	1737	1388	
1420	1451		1363	1885	1466	1797	1838	
1500	1651		1493	2125	1506			
1530	1951							

<sup>74</sup>See footnote 1, page 10.

Composition: % C 37.0 H 2.2 N 18.5 O 42.3 C/H Ratio 0.549			Molecular Weight: (C <sub>7</sub> H <sub>5</sub> N <sub>3</sub> O <sub>6</sub> )	227
			Oxygen Balance:	
			CO, %	-74
			CO %	-25
			Density: gm/cc	Crystal
Melting Point: °C		81		
Freezing Point: °C				
Impact Sensitivity, 2 Kg Wt:			Boiling Point: °C	
Bureau of Mines Apparatus, cm	95-100+		Refractive Index, n <sub>D</sub> <sup>20</sup>	α 1.5430
Sample Wt 20 mg				β 1.6742
Picatinny Arsenal Apparatus, in.	14-15			γ 1.717
Sample Wt, mg	17			
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	0.10
	%		120°C	0.23
Explosions	4		135°C	0.44
Partials	0		150°C	0.65
Burned	0			
Unaffected	6		200 Gram Bomb Sand Test:	
			Sand, gm	48.0
Explosion Temperature: °C			Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)	570		Minimum Detonating Charge, gm	
1	520		Mercury Fulminate	0.24*
5	475		Lead Azide	0.27*
10	465		*Alternative initiating charges.	
15			Ballistic Mortar, % TNT:	Std=100
20			Trauzl Test, % TNT:	Std=100
75°C International Heat Test:			Plate Dent Test:	(a)
% Loss in 48 Hrs	0.04		Method	A A B
100°C Heat Test:			Condition	Cast Pressed Cast
% Loss, 1st 48 Hrs	0.2		Confined	Yes Yes No
% Loss, 2nd 48 Hrs	0.2		Density, gm/cc	1.61 1.50 1.61
Explosion in 100 Hrs	None		Brisance, % TNT	100 100 100
Flammability Index: (b)	100		Detonation Rate:	
Hygroscopicity: % 30°C, 90% RH	0.03		Confinement	Unconfined Unconfined
Volatility: 30°C	Ni 1		Condition	Pressed Cast
			Charge Diameter, in.	1.0 1.0
			Density, gm/cc	1.56 1.56
			Rate, meters/second	6825 6640

<p>Booster Sensitivity Test: (c)</p> <p>Condition Pressed Cast</p> <p>Tetryl, gm 100 100</p> <p>Wax, in. for 50% Detonation 1.68 0.82</p> <p>Wax, gm</p> <p>Density, gm/cc 1.55 1.60</p>	<p>Decomposition Equation: (h) (i)</p> <p>Oxygen, atoms/sec <math>10^{11.4}</math> <math>10^{12.2}</math></p> <p>(Z/sec)</p> <p>Heat, kilocalorie/mole 34.4 43.4</p> <p>(AH, kcal/mol)</p> <p>Temperature Range, °C 275-310 238-277</p> <p>Phase Liquid Liquid</p>																													
<p>Heat of: (d)</p> <p>Combustion, cal/gm 3620</p> <p>Explosion, cal/gm 1080</p> <p>Gas Volume, cc/gm 730</p> <p>Formation, cal/gm 78.5</p> <p>Fusion, cal/gm 22.34</p> <p>Temperature, °C 79</p>	<p>Armor Plate Impact Test:</p> <p>60 mm Mortar Projectile: (j)</p> <p>50% Inert, Velocity, ft/sec &gt;1100</p> <p>Aluminum Fineness</p> <p>500-lb General Purpose Bombs: (j)</p> <table border="1"> <thead> <tr> <th>Plate Thickness, inches</th> <th>Trials</th> <th>% Inert</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td></td> </tr> <tr> <td>1¼</td> <td>0</td> <td></td> </tr> <tr> <td>1½</td> <td>4</td> <td>100</td> </tr> <tr> <td>1¾</td> <td>4</td> <td>50</td> </tr> </tbody> </table>	Plate Thickness, inches	Trials	% Inert	1	0		1¼	0		1½	4	100	1¾	4	50														
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<p>Burning Rate:</p> <p>cm/sec</p>																														
<p>Thermal Conductivity:</p> <p>cal/sec/cm/°C See next page.</p>																														
<p>Coefficient of Expansion: (b)</p> <p>Linear, %/°C -40° to 60°C <math>5.4 \times 10^{-5}</math> (b)</p> <p>-40° to 60°C <math>6.7 \times 10^{-5}</math> (b)</p> <p>Volume, %/°C 27° to 80°C <math>16 \times 10^{-5}</math> (b)</p> <p>16° to 70°C <math>26.3 \times 10^{-5}</math> (n)</p>	<p>Bomb Drop Test:</p>																													
<p>hardness, Mohs' Scale: (e) 1.4</p>	<p>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p>																													
<p>Young's Modulus: (b)</p> <p>E', dynes/cm<sup>2</sup> <math>5.45 \times 10^{10}</math></p> <p>E, lb/inch<sup>2</sup> <math>0.79 \times 10^6</math></p> <p>Density, gm/cc 161</p>	<p>Max Safe Drop, ft 5000-6000</p>																													
<p>Compressive Strength: lb/inch<sup>2</sup> 13800-14000</p> <p>Density, gm/cc 1.62</p>	<p>500-lb General Purpose Bomb vs Concrete:</p>																													
<p>Vapor Pressure: (r)</p> <table border="1"> <thead> <tr> <th>°C</th> <th>mm Mercury</th> </tr> </thead> <tbody> <tr> <td>80</td> <td>0.042</td> </tr> <tr> <td>85</td> <td>0.053</td> </tr> <tr> <td>90</td> <td>0.067</td> </tr> <tr> <td>95</td> <td>0.085</td> </tr> <tr> <td>100</td> <td>0.106</td> </tr> </tbody> </table>	°C	mm Mercury	80	0.042	85	0.053	90	0.067	95	0.085	100	0.106	<table border="1"> <thead> <tr> <th rowspan="2">Height, ft</th> <th>No Seal</th> <th>Seal</th> </tr> </thead> <tbody> <tr> <td>4,000</td> <td>4-5,000</td> </tr> <tr> <td>Trials</td> <td>26</td> <td>20</td> </tr> <tr> <td>Unaffected</td> <td>24</td> <td>20</td> </tr> <tr> <td>Low Order</td> <td>2</td> <td>0</td> </tr> <tr> <td>High Order</td> <td>0</td> <td>0</td> </tr> </tbody> </table>	Height, ft	No Seal	Seal	4,000	4-5,000	Trials	26	20	Unaffected	24	20	Low Order	2	0	High Order	0	0
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TNT (Trinitrotoluene)

<b>Fragmentation Test:</b>		<b>Shaped Charge Effectiveness, TNT = 100:</b>	
<b>90 mm HE, M71 Projectile, Lot WC-91:</b>		Glass Cones	Steel Cones
Density, gm/cc	1.60	Hole Volume	100
Charge Wt, lb	2.104	Hole Depth	100
<b>Total No. of Fragments:</b>		<b>Color:</b> Light, yellow	
For TNT	703	<b>Principal Uses:</b> GP bombs, HE projectiles, demolition charges, depth charges, grecoades, propellant compositions	
For Subject HE	703		
<b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>		<b>Method of Loading:</b> 1. Cast 2. Pressed	
Density, gm/cc	1.60	<b>Loading Density: gm/cc</b> See below	
Charge Wt, lb	0.848		
<b>Total No. of Fragments:</b>		<b>Storage:</b>	
For TNT	514		
For Subject HE	514	Method	Dry
<b>Fragment Velocity: ft/sec</b> (k)		Hazard Class (Quantity-Distance)	Class 9
At 9 ft	260	Compatibility Group	Group I
At 25 1/4 ft	236	Exudation	None at 65°C
Density, gm/cc	1.5	<b>Loading Density: gm/cc</b>	
<b>Blast (Relative to</b>		1. Cast 1.58-1.59 2. Pressed psi x 10 <sup>3</sup>	
<b>Air:</b>		3 5 10 15 20 30 50	
Peak Pressure	100	1.35	1.40 1.45 1.52 1.55 1.59 1.6
Impulse	100	<b>Thermal Conductivity:</b>	
	100	cal/sec/cm/°C	
<b>Air, Confined:</b>		Density 1.19 gm/cc (g) 5.28 x 10 <sup>-4</sup>	
Impulse	100	1.51 gm/cc (g) 7.12 x 10 <sup>-4</sup>	
<b>Under Water:</b>		1.54 gm/cc (b) 5.6 x 10 <sup>-4</sup>	
Peak Pressure	100	1.67 gm/cc (g) 12.21 x 10 <sup>-4</sup>	
Impulse	100	<b>Viscosity, poises:</b>	
	100	Temp, 85°C 0.139	
<b>Underground:</b>		100°C 0.095	
Peak Pressure	100	Bulk Modulus at Room	
Impulse	100	Temperature (25°-30°C) (m)	
Energy	100	Dynes/cm <sup>2</sup> x 10 <sup>-10</sup> 2.92	
		Density, gm/cc 1.56	



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:

<u>°C</u>	<u>inches</u>
-40	17
Room	14
80	7
90	3
105-110	2 (5 expl in 20 trials)

Impact Sensitivity versus Loading Method, Large Impact Apparatus, Inches:

Pressed at 1.60 gm/cc	70
Cast at 1.60 gm/cc	26

Rifle Bullet Impact Sensitivity versus Temperature, Confinement:

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

Explosion Temperature versus TNT Initial Temperature:

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

Explosion Temperature versus Confinement, °C:

Unconfined	Decomposes	470
Sealed in glass capillary	Explodes	320-335

Viscosity at 80.5°C:

Viscosity, X, cp  $\log X = 0.046 S + 1.26$   
 S = % solid in slurry  
 Particle size effect, small

Density, gm/cc:

<u>°C</u>	<u>State</u>	<u>gm/cc</u>
27 to 70	Flaked	1.65
80	Flaked	1.64
82	Liquid	1.48
87	Liquid	1.48
95	Liquid	1.47

Solubility of TNT, gm/100 gm (%), in: (f)

<u>Water</u>		<u>Acetone</u>		<u>Benzene</u>		<u>Toluene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.0100	0	57	0	13	0	28
20	0.0130	20	109	20	67	20	135
40	0.0285	40	228	40	180	40	367
60	0.0675	60	600	60	478	60	367
				80	? 2000	80	>1700

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

TNT (Trinitrotoluene)

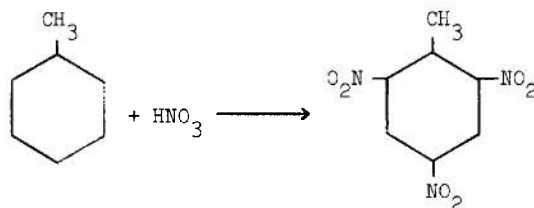
<u>Pyridine</u>		<u>Methyl acetate</u>		<u>Ethylene dichloride</u>		<u><math>\beta</math>-Ethoxy-ethyl-acetate</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	140	20	73	20	34	20	29.5
40	250	40	135	40	123	40	49
60	640	50	280	60	460	50	96
70	1250						

<u>Tetrachloro-ethane</u>		<u>Aniline</u>		<u>Isopropyl alcohol</u>		<u>Ethanol</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
20	18	10	6.1	20	0.76	0	0.62
40	50	30	11.5	40	1.96	20	1.25
50	100	50	29	50	2.95	40	2.85
		70	74			60	8.4
		80	130			70	15

<u>Isobutyl alcohol</u>		<u>Carbon disulfide</u>		<u>Chlorobenzene</u>	
<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>	<u>°C</u>	<u>%</u>
0	0.20	0	0.14	20	55
20	0.61	20	0.44	30	51
40	1.41	40	1.4	40	79
50	2.35			50	116

Preparation:

(AC 7258, 7259, 7260 - Nitration Kinetics)  
 (Chemistry of Powder and Explosives, Davis)



In older processes trinitrotoluene (TNT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TNT at a cost of a little less than 6¢/lb. In England, a two stage continuous process was developed during World War II; in the first counter current stage, toluene was nitrated to the mono stage mononitrotoluene (MNT); in the second stage, also counter current, MNT was nitrated to TNT.

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxy ion ( $\text{NO}_2^+$ ), on the one hand, and the role of the bisulfate ion ( $\text{HSO}_4^-$ ) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNE:

$$\frac{d(\text{TNT})}{dt} = K (\text{NO}_2^+) [K' (\text{HSO}_4^-) + K'' (\text{H}_2\text{SO}_4)] (\text{DNE})$$

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  $\text{SO}_3$ ) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% oleum is slowly added, under good agitation at 100°-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 Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind, 1891, p. 1028). After 1901 TNT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TNT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthetic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TNT for melt-loading and its extensive use in binary and ternary explosive mixtures, TNT is considered the most important military explosive known today.

#### Destruction by Chemical Decomposition:

TNT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide ( $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ ) in 6 parts of water.

#### References:<sup>75</sup>

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

<sup>75</sup>See footnote 1, page 10.

(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, PAIR No. 2383, November 1956.

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

(n) Mantrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.

(o) Also see the following Picatinny Arsenal Technical Reports on TNT:

<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
10	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	1258	1109
1500	1821	1472	1323	1454	1425	1756	1427	1308	1129

## AMCP 706-177

TNT (Trinitrotoluene)

<u>0</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
1530	1492	1373	1524	1435	1956	1437	1318	1139
1540	1562	1493	1544	1445	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

Composition: %		Molecular Weight:	97
RDX	42	Oxygen Balance:	
TNT	40	CO, %	-55
Aluminum	18	CO %	-26
C/H Ratio		Density: gm/cc	Cast 1.76-1.81
		Melting Point: °C	
		Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt:		Boiling Point: °C	
Bureau of Mines Apparatus, cm	42	Refractive Index, $n_{20}^D$	
Sample Wt 20 mg		$n_{25}^D$	
Picatinny Arsenal Apparatus, in.	9	$n_{30}^D$	
Sample Wt, mg	15		
Friction Pendulum Test:		Vacuum Stability Test:	
Steel Shoe		cc/40 Hrs, at	
Fiber Shoe		90°C	
		100°C	
Rifle Bullet Impact Test: Trials		120°C	1.0
	%	135°C	
Explosions	20	150°C	
Partials	80	200 Gram Bomb Sand Test:	
Burned	0	Sand, gm	59.5
Unaffected	0		
Explosion Temperature: °C		Sensitivity to Initiation:	
Seconds, 0.1 (no cap used)		Minimum Detonating Charge, gm	
1		Mercury Fulminate	0.18
5 Decomposes	260	Lead Azide	
10		Tetryl	
15			
20		Ballistic Mortar, % TNT: (a)	138
		Trauzl Test, % TNT: (b)	164
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	0.00	Confined	No
% Loss, 2nd 48 Hrs	0.10	Density, gm/cc	1.83
Explosion in 100 Hrs	None	Brisance, % TNT	120
Flammability Index:	196	Detonation Rate: (d)	
		Confinement	None
Hygroscopicity: % 30°C, 90% RH	0.00	Condition	Cast
		Charge Diameter, in.	1.0
Volatility:		Density, gm/cc	1.81
		Rate, meters/second	7495

<p>Booster Sensitivity Test: (c)</p> <table border="1"> <tr> <td>Condition</td> <td>Pressed</td> <td>Cast</td> </tr> <tr> <td>Tetryl, gm</td> <td>10</td> <td>5</td> </tr> <tr> <td>Wax, in. for 50% Detonation</td> <td></td> <td></td> </tr> <tr> <td>Wax, gm</td> <td>2</td> <td>0</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.64</td> <td>1.81</td> </tr> </table>	Condition	Pressed	Cast	Tetryl, gm	10	5	Wax, in. for 50% Detonation			Wax, gm	2	0	Density, gm/cc	1.64	1.81	<p>Decomposition Equation:</p> <p>Oxygen, atoms/sec (Z/sec)</p> <p>Heat, kilocalorie/mole (AH, kcal/mol)</p> <p>Temperature Range, °C</p> <p>Phase</p>
Condition	Pressed	Cast														
Tetryl, gm	10	5														
Wax, in. for 50% Detonation																
Wax, gm	2	0														
Density, gm/cc	1.64	1.81														
<p>Heat of: (a)</p> <table border="1"> <tr> <td>Combustion, cal/gm</td> <td>3740</td> </tr> <tr> <td>Explosion, cal/gm</td> <td>1800</td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td></td> </tr> <tr> <td>Formation, cal/gm</td> <td></td> </tr> <tr> <td>Fusion, cal/gm</td> <td></td> </tr> </table>	Combustion, cal/gm	3740	Explosion, cal/gm	1800	Gas Volume, cc/gm		Formation, cal/gm		Fusion, cal/gm		<p>Armor Plate Impact Test:</p> <p>60 mm Mortar Projectile: (a)</p> <p>50% Inert, Velocity, ft/sec 185</p> <p>Aluminum Fineness</p> <p>500-lb General Purpose Bombs:</p> <p>Plate Thickness, inches</p> <p>1</p> <p>1¼</p> <p>1½</p> <p>1¾</p>					
Combustion, cal/gm	3740															
Explosion, cal/gm	1800															
Gas Volume, cc/gm																
Formation, cal/gm																
Fusion, cal/gm																
<p>Specific Heat: cal/gm/°C (b)</p> <table border="1"> <tr> <td>At -5°C</td> <td>0.22</td> </tr> <tr> <td>Density, gm/cc</td> <td>1.82</td> </tr> <tr> <td>At 15°C</td> <td>0.24</td> </tr> </table>	At -5°C	0.22	Density, gm/cc	1.82	At 15°C	0.24	<p>Bomb Drop Test:</p> <p>17, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft</p> <p>500-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p> <p>1000-lb General Purpose Bomb vs Concrete:</p> <p>Height, ft</p> <p>Trials</p> <p>Unaffected</p> <p>Low Order</p> <p>High Order</p>									
At -5°C	0.22															
Density, gm/cc	1.82															
At 15°C	0.24															
<p>Burning Rate:</p> <p>cm/sec</p>																
<p>Thermal Conductivity: (b)</p> <table border="1"> <tr> <td>cal/sec/cm/°C</td> <td><math>9.7 \times 10^{-4}</math></td> </tr> <tr> <td>Density, gm/cc</td> <td>1.82</td> </tr> </table>	cal/sec/cm/°C	$9.7 \times 10^{-4}$	Density, gm/cc	1.82												
cal/sec/cm/°C	$9.7 \times 10^{-4}$															
Density, gm/cc	1.82															
<p>Coefficient of Expansion:</p> <p>Linear, %/°C -73 to 75°C <math>4.7 \times 10^{-5}</math> (b)</p> <p>Volume, %/°C</p>																
<p>Hardness, Mohs' Scale:</p>																
<p>Young's Modulus: (b)</p> <table border="1"> <tr> <td>E, dynes/cm<sup>2</sup></td> <td><math>9.53 \times 10^{10}</math></td> </tr> <tr> <td>E, lb/inch<sup>2</sup></td> <td><math>1.38 \times 10^6</math></td> </tr> <tr> <td>Density, gm/cc</td> <td>1.77</td> </tr> </table>	E, dynes/cm <sup>2</sup>	$9.53 \times 10^{10}$	E, lb/inch <sup>2</sup>	$1.38 \times 10^6$	Density, gm/cc	1.77										
E, dynes/cm <sup>2</sup>	$9.53 \times 10^{10}$															
E, lb/inch <sup>2</sup>	$1.38 \times 10^6$															
Density, gm/cc	1.77															
<p>Compressive Strength: lb/inch<sup>2</sup> (b) 2100-2300</p> <p>Density, gm/cc 1.77</p>																
<p>Vapor Pressure:</p> <p>°C mm Mercury</p>																



<p>Fragmentation Test:</p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.75                  Charge Wt, lb 2.316</p> <p>Total No. of Fragmentt:                  For TNT 703                  For Subject HE 891</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.79                  Charge Wt, lb 0.940</p> <p>Total No. of Fragments:                  For TNT 514                  For Subject HE 647</p>	<p>Shaped Charge Effectiveness, TNT = 100:  <u>50/36.5/13.5</u></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td>150</td> <td>145</td> </tr> <tr> <td>Hole Depth</td> <td>127</td> <td>131</td> </tr> </tbody> </table>		Glass Cones	Steel Cones	Hole Volume	150	145	Hole Depth	127	131			
	Glass Cones	Steel Cones											
Hole Volume	150	145											
Hole Depth	127	131											
<p>Fragment Velocity: ft/sec                  At 9 ft 2960                  At 25½ ft 2800                  Density, gm/cc --</p>	<p>Color: Gray</p> <p>Principal Uses: Depth charges, bombs</p> <p>Method of Loading: Cast</p> <p>Loading Density: gm/cc 1.76-1.81</p>												
<p>Blast (Relative to TNT): (e)</p> <p>Air:                  Peak Pressure 122                  Impulse 125                  Energy 146</p> <p>Air, Confined:                  Impulse 116</p> <p>Under Water:                  Peak Pressure 116                  Impulse 127                  Energy 153</p> <p>Underground:                  Peak Pressure                  Impulse                  Energy</p>	<p>Storage:</p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation</p> <p><u>Effect of Temperature on Impact Sensitivity:</u></p> <table border="1"> <thead> <tr> <th><u>Temp.</u> <u>°C</u></th> <th><u>PA Impact Test</u> <u>2 Kg Wt. inches</u></th> </tr> </thead> <tbody> <tr> <td>25</td> <td>15</td> </tr> <tr> <td>32</td> <td>7</td> </tr> <tr> <td>104</td> <td>8</td> </tr> </tbody> </table> <p><u>Viscosity, poises:</u></p> <table border="1"> <tbody> <tr> <td>Temp, 83°C</td> <td>4.5</td> </tr> <tr> <td>95°C</td> <td>2.3</td> </tr> </tbody> </table>	<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt. inches</u>	25	15	32	7	104	8	Temp, 83°C	4.5	95°C	2.3
<u>Temp.</u> <u>°C</u>	<u>PA Impact Test</u> <u>2 Kg Wt. inches</u>												
25	15												
32	7												
104	8												
Temp, 83°C	4.5												
95°C	2.3												

TorpexPreparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDX is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued stirring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDX/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Torpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in service munitions:

	<u>Torpex 2</u> <u>unwaxed</u>	<u>Torpex 2</u> <u>waxed</u>	<u>Torpex 3</u>
	(a)	(b)	(c)
RDX, %	42	41.6	41.4
TNT, %	40	39.7	39.5
Aluminum, %	18	18.0	17.9
Wax, %		0.7	0.7
Calcium chloride, %			0.5

- (a) Made from Composition B-2 or 60/40 Cyclotol.  
 (b) Made by the addition of aluminum to Composition B.  
 (c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to coagulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.66-1.70 for waxed torpex, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torpex. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References:<sup>76</sup>

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.  
 (b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.  
 (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.  
 L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

<sup>76</sup>See footnote 1, page 10.

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

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

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

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

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

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

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

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones      Steel Cones</p> <p>Hole Volume                  Hole Depth</p> <hr/> <p><b>Color:</b> <span style="float: right;">Yellow</span></p> <hr/> <p><b>Principal Uses:</b></p> <hr/> <p><b>Method of Loading:</b> <span style="float: right;">Pressed</span></p> <hr/> <p><b>Loading Density:</b> gm/cc                  At 50,000 psi <span style="float: right;">1.80</span></p>														
<p><b>Fragment Velocity:</b> ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method <span style="float: right;">Dry</span></p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation</p>														
<p><b>Blost (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Detonation Velocity:</b> <span style="float: right;">(a, b, c)</span></p> <table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: left;"><u>Density, gm/cc</u></th> <th style="text-align: right;"><u>Meters/sec</u></th> </tr> </thead> <tbody> <tr> <td>1.290</td> <td style="text-align: right;">5380</td> </tr> <tr> <td>1.345</td> <td style="text-align: right;">5628</td> </tr> <tr> <td>1.675</td> <td style="text-align: right;">6550</td> </tr> <tr> <td>1.675</td> <td style="text-align: right;">6575</td> </tr> <tr> <td>1.882</td> <td style="text-align: right;">7035</td> </tr> <tr> <td>1.835</td> <td style="text-align: right;">7220</td> </tr> </tbody> </table> <p><b>Heat of:</b></p> <p>Explosion, cal/gm <span style="float: right;">2831</span></p>	<u>Density, gm/cc</u>	<u>Meters/sec</u>	1.290	5380	1.345	5628	1.675	6550	1.675	6575	1.882	7035	1.835	7220
<u>Density, gm/cc</u>	<u>Meters/sec</u>														
1.290	5380														
1.345	5628														
1.675	6550														
1.675	6575														
1.882	7035														
1.835	7220														

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. Flurschein 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. Flurschein 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: \*\*

(a) F. Taylor, Jr., Synthesis of New High Explosives 11, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzene, NAVORD Report No. 4405, 1 November 1956.

(b) L. D. Hampton, Small Scale Detonation Velocity Measurements from May 1951 to May 1954, NAVORD Report No. 3731, June 1954.

(c) E. M. Fisher and E. A. Christian, Explosion Effects Data Sheets, NAVORD Report No. 2986, 14 June 1955.

<sup>77</sup>See footnote 1, page 10.

Composition: % C 29.9 H 5.4 N 11.7 O 53.0 C/H Ratio 0.177 <div style="display: inline-block; vertical-align: middle; margin-left: 20px;"> <math display="block">  \begin{array}{c}  \text{CH}_2\text{ONO}_2 \\  \diagup \\  \text{H}_2\text{C} \\  \diagdown \\  \text{O} \\    \\  \text{H}_2\text{C} \\    \\  \text{H}_2\text{C} \\    \\  \text{H}_2\text{C} \\  \diagdown \\  \text{ONO}_2  \end{array}  </math> </div>	Molecular Weight: (C <sub>6</sub> H <sub>12</sub> N <sub>2</sub> O <sub>8</sub> )	240
	Oxygen Balance: CO, % CO <sub>2</sub> , %	-89 -27
	Density: gm/cc	20°C 1.33 25°C 1.32
	Melting Point: °C	
	Freezing Point: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	100+ 43	Boiling Point: °C
Friction Pendulum Test: Steel Shoe Fiber Shoe	Unaffected Unaffected	Refractive Index, n <sub>D</sub> <sup>20</sup> n <sub>D</sub> <sup>25</sup> n <sub>D</sub> <sup>30</sup>
Rifle Bullet Impact Test: Trials Explosions Particls Burned Unaffected	%    	8 hours 0.45 0.8
Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 10 15 20	223	200 Gram Bomb Sand Test: Sand, gm
75°C International Heat Test: % Loss in 48 Hrs		14.7
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	1.8 1.6 None	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl
Flammability Index:		Ballistic Mortar, % TNT:
Hygroscopicity: %		Trauzl Test, % TNT:
Volatility: 60°C, mg/cm <sup>2</sup> /hr	40	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
		Detonation Rate: Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second
		Shelby steel Liquid 1.25 1.33 Fails

<p>Fragmentation Test:</p> <p><b>90 mm HE, M71</b> Projectile, Lot WC-91:                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1</b> Projectile, Lot KC-5:                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>			Glass Cones	Steel Cones	Hole Volume			Hole Depth		
		Glass Cones	Steel Cones								
	Hole Volume										
	Hole Depth										
<p><b>Color:</b></p>											
<p>Principal Uses: Ingredient of rocket and double base propellants</p>											
<p>Fragment Velocity: ft/sec                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p>Method of Loading:</p>										
	<p>Loading Density: gm/cc</p>										
<p>Blast (Relative to TNT):</p> <p>Air:                  Peak Pressure                  Impulse                  Energy</p> <p>Air, Confined:                  Impulse</p> <p>Under Water:                  Peak Pressure                  Impulse                  Energy</p> <p>Underground:                  Peak Pressure                  Impulse                  Energy</p>	<p>Storage:</p> <table border="0"> <tr> <td>Method</td> <td>Liquid</td> </tr> <tr> <td>Hazard Class (Quantity-Distance)</td> <td></td> </tr> <tr> <td>Compatibility Group</td> <td></td> </tr> <tr> <td>Exudation</td> <td></td> </tr> </table>		Method	Liquid	Hazard Class (Quantity-Distance)		Compatibility Group		Exudation		
	Method	Liquid									
	Hazard Class (Quantity-Distance)										
	Compatibility Group										
	Exudation										
	<p><u>Solubility in Water,</u>  <u>gm/100 gm. at:</u></p> <table border="0"> <tr> <td>25°C</td> <td>0.55</td> </tr> <tr> <td>60°C</td> <td>0.68</td> </tr> </table>		25°C	0.55	60°C	0.68					
	25°C	0.55									
	60°C	0.68									
	<p><u>Solubility, gm/100 gm.</u>  <u>at 25°C, in:</u></p> <table border="0"> <tr> <td>Ether</td> <td>w</td> </tr> <tr> <td>Alcohol</td> <td>∞</td> </tr> <tr> <td>2: 1 Ether:Alcohol</td> <td>w</td> </tr> <tr> <td>Acetone</td> <td>w</td> </tr> </table>		Ether	w	Alcohol	∞	2: 1 Ether:Alcohol	w	Acetone	w	
	Ether	w									
Alcohol	∞										
2: 1 Ether:Alcohol	w										
Acetone	w										
<p><u>Viscosity, centipoises:</u></p> <table border="0"> <tr> <td>Temp, 20°C</td> <td>13.2</td> </tr> </table>		Temp, 20°C	13.2								
Temp, 20°C	13.2										
<p><u>Hydrolysis, % Acid:</u></p> <table border="0"> <tr> <td>10 days at 22°C</td> <td>0.032</td> </tr> <tr> <td>5 days at 60°C</td> <td>0.029</td> </tr> </table>		10 days at 22°C	0.032	5 days at 60°C	0.029						
10 days at 22°C	0.032										
5 days at 60°C	0.029										
<p><u>Heat of:</u></p> <table border="0"> <tr> <td>Combustion, cal/gm</td> <td>3428</td> <td></td> </tr> <tr> <td>Explosion, cal/gm</td> <td>357</td> <td></td> </tr> <tr> <td>Gas Volume, cc/gm</td> <td>851</td> <td></td> </tr> </table>		Combustion, cal/gm	3428		Explosion, cal/gm	357		Gas Volume, cc/gm	851		
Combustion, cal/gm	3428										
Explosion, cal/gm	357										
Gas Volume, cc/gm	851										
<p><u>Japor Pressure:</u></p> <table border="0"> <tr> <td>°C</td> <td></td> <td>mm Mercury</td> </tr> <tr> <td>25</td> <td></td> <td>&lt; 0.001</td> </tr> </table>		°C		mm Mercury	25		< 0.001				
°C		mm Mercury									
25		< 0.001									



Origin:

Lourenco prepared triethylene glycol in 1863 by heating glycol with ethylene bromide in a sealed tube at 115<sup>o</sup>-120<sup>o</sup>C (Ann (3) 67, 275). Later in the same year Wurtz prepared triethylene glycol by heating ethylene oxide with glycol at 100<sup>o</sup>C. By action of nitric acid triethylene glycol was oxidized to (H<sub>2</sub>OOC·CH<sub>2</sub>·O-CH<sub>2</sub>)<sub>2</sub> (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vigreux fractionating column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180<sup>o</sup>C, and a take-off temperature of approximately 120<sup>o</sup>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<sup>o</sup>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<sup>o</sup>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: <sup>78</sup>

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

<u>3</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1953	1745	1786	1767	1638
2193		2056	1817	

<sup>78</sup>See footnote 1, page 10.

Composition: % Picric Acid 88 - 90 Mononitronaphthalene 12 - 10	Molecular Weight: <sup>2</sup>	217
	<b>Oxygen Balance:</b>	
	CO <sub>2</sub> %	-62
	CO %	-14
	Density: gm/cc	Cast
	Melting Point: °C	90
	int: °C	
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 10	Boiling Point: °C	Exp 1000
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>	
Friction Pendulum Test: Steel Shoe Fiber Shoe	Vacuum Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C	0.9
Rifle Bullet Impact Test: Trials	200 Gram Bomb Sand Test:	
Explosions 0	Sand, gm	44.2
Partials 0		
Burned 0	Sensitivity to Initiation:	
Unaffected 100	Minimum Detonating Charge, gm	
	Mercury Fulminate	0.20
	Lead Azide	0.04
	Tetryl	
	Ballistic Mortar, % TNT:	
	Traul Test, % TNT:	
Explosion Temperature: °C	Plate Dent Test:	
Seconds, 0.1 (no cap used)	Method	
1	Condition	
5 Decomposes 315	Confined	
10	Density, gm/cc	
15	Brisance, % TNT	
20	Detonation Rate:	
	Confinement	None
75°C International Heat Test: % Loss in 48 Hrs	Condition	Cast
	Charge Diameter, in.	1.0
100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Density, gm/cc	1.60
	Rate, meters/second	7020
Flammability Index:		
Hygroscopicity: %		
Volatility:		

<p><b>Fragmentation test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p>
	<p><b>Color:</b></p>
	<p><b>Principal Uses:</b> TNT substitute in projectiles and bombs</p>
	<p><b>Method of Loading:</b> Cast</p>
	<p><b>Loading Density: gm/cc</b> 1.60</p>
<p><b>Fragment Velocity: ft/sec</b> At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance) Class 9</p> <p>Compatibility Group Group I</p> <p>Exudation Exude at 50°C</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	<p><b>Preparation:</b></p> <p>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.</p>

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:<sup>79</sup>

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

<u>2</u>	<u>5</u>	<u>6</u>	<u>8</u>
1352	1325	926	1098
1372		976	1838

<sup>79</sup>See footnote 1, page 10.

<b>Composition:</b> % C 18.6 H 1.6 N 21.8 O 58.0 C/H Ratio 0.202 <div style="text-align: center; margin-top: 10px;"> <math display="block">  \begin{array}{c}  \text{O}-\text{CH}_2\text{C}(\text{NO}_2)_3 \\  \diagdown \\  \text{C} = \text{O} \\  \diagup \\  \text{CH}_2\text{CH}_2\text{C}(\text{NO}_2)_3  \end{array}  </math> </div>	<b>Molecular Weight:</b> (C <sub>6</sub> H <sub>6</sub> N <sub>6</sub> O <sub>14</sub> ) 386	
	<b>Oxygen Balance:</b>	
	CO, %	-4.2
	CO %	20.8
	<b>Density:</b> gm/cc	Form I
<b>Melting Point:</b> °C 93		
<b>Freezing Point:</b> °C		
<b>Boiling Point:</b> °C		
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 50% point, cm (a) 20	<b>Refractive Index, n<sub>20</sub><sup>D</sup></b> Form I (e)	
	<u>Crystal Axis</u>	
	α	1.518
	β	1.527
	γ	1.546
<b>Friction Pendulum Test:</b> Steel Shoe Fiber Shoe	<b>Vacuum Stability test:</b>	
	cc/40 Hrs, at	
	90°C	----
	100°C 48 hrs	0.60
	120°C	
	135°C	
	150°C	
<b>Rifle Bullet Impact Test:</b> Trials % Explosions Partial Burned Unaffected	<b>200 Gram Bomb Sand test:</b>	
		Sand, gm
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) --- 1 --- 5 50% point (Alhot bar) (a) 225 10 15 20	<b>Sensitivity to Initiation:</b>	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	
	Lead Azide	
	Tetryl	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs	<b>Ballistic Mortar, % TNT:</b> (b) 136	
	<b>Trauzl Test, % TNT:</b>	
<b>100°C Heat Test:</b> % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	<b>Plate Dent Test:</b>	
	Method	
	Condition	
	Confined	
	Density, gm/cc	
	Brisance, % TNT	
<b>Flammability Index:</b>	<b>Detonation Rate:</b>	
	Confinement	
<b>Hygroscopicity:</b> % 30°C, 90% RH 75°C, 5 months Nil (a)	Condition	
	Charge Diameter, in.	
<b>Volatility:</b>	Density, gm/cc	1.60 1.76
	Rate, meters/second	7760 8290

Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc	Decomposition Equation: Oxygen, atoms/sec $4.4 \times 10^{21}$ (Z/sec) Heat, kilocalorie/mole <b>43.4</b> ( $\Delta H$ , kcal/mol) Temperature Range, °C Phase Liquid											
Heat of: Combustion, cal/gm <b>1685</b> Explosion, cal/gm Gas Volume, cc/gm Formation, cal/gm <b>307</b> Fusion, cal/gm Sublimation, cal/gm (est) <b>804</b>	Armor Plate Impact Test:  60 mm Mortar Projectile: 50% Inert, Velocity, ft/sec Aluminum Fineness  500-lb General Purpose Bombs:  Plate Thickness, inches  1 1¼ 1½ 1¾											
Specific Heat: cal/gm/°C	Bomb Drop Test:  <b>T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</b>  Max Safe Drop, ft  <b>500-lb General Purpose Bomb vs Concrete:</b>  Height, ft <b>Trials</b> Unaffected Low Order High Order  <b>1000-lb General Purpose Bomb vs Concrete:</b>  Height, ft Trials Unaffected Low Order High Order											
Burning Rate: cm/sec												
Thermal Conductivity: col/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) <table border="0"> <tr> <td>°C</td> <td>mm Mercury</td> </tr> <tr> <td>65</td> <td><math>3.3 \times 10^{-4}</math></td> </tr> <tr> <td><b>75</b></td> <td>1.3 x</td> </tr> <tr> <td>85</td> <td><math>4.2 \times 10^{-3}</math></td> </tr> <tr> <td>100</td> <td><math>2.3 \times 10^{-3}</math></td> </tr> <tr> <td><b>120</b></td> <td><math>1.4 \times 10^{-2}</math></td> </tr> </table>	°C	mm Mercury	65	$3.3 \times 10^{-4}$	<b>75</b>	1.3 x	85	$4.2 \times 10^{-3}$	100	$2.3 \times 10^{-3}$	<b>120</b>	$1.4 \times 10^{-2}$
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<p>Fragmentation Test:</p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p>Total No. of Fragments:                  For TNT                  For Subject HE</p>	<p>Shaped Charge Effectiveness, TNT = 100:</p> <table border="0"> <tr> <td></td> <td style="text-align: center;"><b>Glass Cones</b></td> <td style="text-align: center;"><b>Steel Cones</b></td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		<b>Glass Cones</b>	<b>Steel Cones</b>	Hole Volume			Hole Depth													
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Hole Volume																					
Hole Depth																					
<p>Fragment Velocity: ft/sec                  * At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p>Color: <span style="float: right;">Colorless</span></p>																				
<p>Blast (Relative to H-6): <u>Sphere</u>    <u>Cylinder (h)</u></p> <table border="0"> <tr> <td><b>Air: 1-lb Charge:</b></td> <td><u>EW*</u></td> <td><u>EV*</u></td> <td><u>EW*</u></td> <td><u>EV*</u></td> </tr> <tr> <td>Peak Pressure</td> <td>0.91</td> <td>0.84</td> <td>0.81</td> <td>0.75</td> </tr> <tr> <td>Impulse</td> <td>0.73</td> <td>0.67</td> <td>0.74</td> <td>0.69</td> </tr> <tr> <td>Energy</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	<b>Air: 1-lb Charge:</b>	<u>EW*</u>	<u>EV*</u>	<u>EW*</u>	<u>EV*</u>	Peak Pressure	0.91	0.84	0.81	0.75	Impulse	0.73	0.67	0.74	0.69	Energy					<p>Principal Uses:</p>
<b>Air: 1-lb Charge:</b>	<u>EW*</u>	<u>EV*</u>	<u>EW*</u>	<u>EV*</u>																	
Peak Pressure	0.91	0.84	0.81	0.75																	
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<p>Underground:                  Peak Pressure                  Impulse                  Energy</p> <p>*EW, equivalent weight of H-6 for a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance.</p>	<p>Method of Loading:</p> <table border="0"> <tr> <td>Loading Density: gm/cc</td> <td>Form I</td> <td>1.783</td> </tr> <tr> <td></td> <td>Form II</td> <td>1.577</td> </tr> <tr> <td></td> <td>Liquid, 99°C,</td> <td>1.551</td> </tr> </table>	Loading Density: gm/cc	Form I	1.783		Form II	1.577		Liquid, 99°C,	1.551											
Loading Density: gm/cc	Form I	1.783																			
	Form II	1.577																			
	Liquid, 99°C,	1.551																			
	<p>Storage:</p> <p>Method <span style="float: right;">Wet</span></p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation</p>																				
	<p><u>Bruceton Safety Test Results:</u> (g)</p> <p>Mean and standard deviation of lengths of 0.300 diameter cylinder across which initiation is possible for 50% certainty:</p> <table border="0"> <tr> <td>TNT</td> <td>0.391</td> <td>±</td> <td>0.040</td> </tr> <tr> <td>RDX Comp B</td> <td>0.381</td> <td>±</td> <td>0.042</td> </tr> <tr> <td>TNETB</td> <td>0.920</td> <td>±</td> <td>0.059</td> </tr> </table> <p><u>Absolute Viscosity, poises:</u> (c)</p> <table border="0"> <tr> <td>Temp, 98.9°C</td> <td>0.173</td> </tr> <tr> <td>106.5°C</td> <td>0.138</td> </tr> </table>	TNT	0.391	±	0.040	RDX Comp B	0.381	±	0.042	TNETB	0.920	±	0.059	Temp, 98.9°C	0.173	106.5°C	0.138				
TNT	0.391	±	0.040																		
RDX Comp B	0.381	±	0.042																		
TNETB	0.920	±	0.059																		
Temp, 98.9°C	0.173																				
106.5°C	0.138																				

Solubility (Room Temperature): (a)

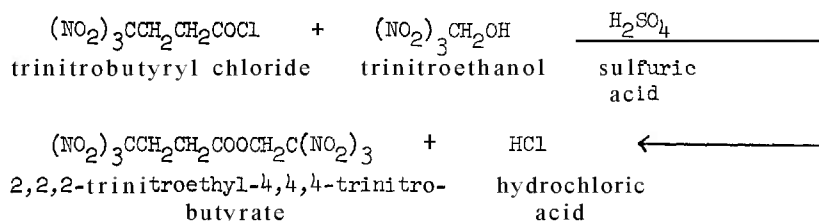
Solvent	Solubility
Water	Insoluble
n-Hexane	Insoluble
Carbon tetrachloride	Insoluble
Ethanol	5 gm/100 gm solvent
Chloroform	5 gm/100 gm solvent
Benzene	10 gm/100 gm solvent
Nitromethane	Very soluble
Glacial acetic acid	Very soluble
Ethyl acetate	Very soluble

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 <sub>4</sub> H <sub>6</sub> N <sub>4</sub> O <sub>7</sub> 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: (a)

Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitroethanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid or fortified H<sub>2</sub>SO<sub>4</sub>, 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.

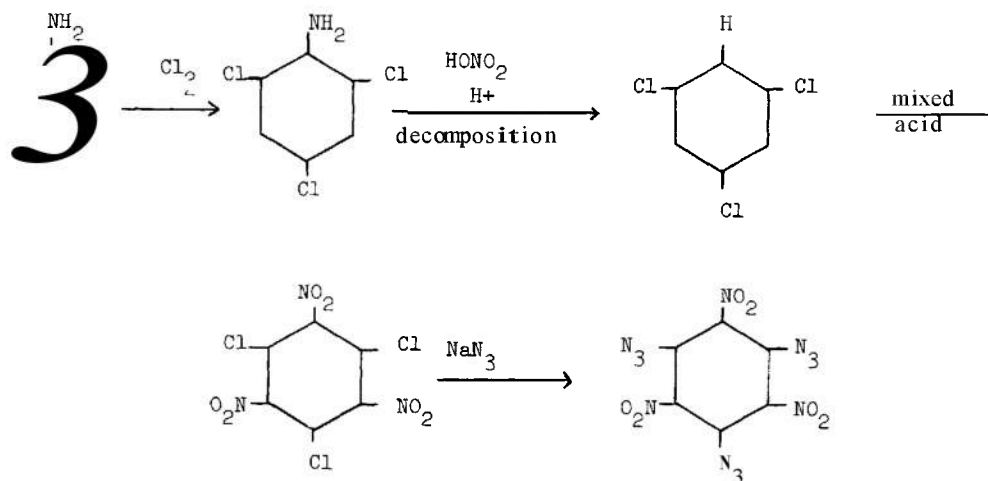
References:<sup>80</sup>

- (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, IX: Selected Physico-Chemical Data of Ten Pure High Explosives, NAVORD Report No. 6130, 18 June 1958.

<sup>80</sup>See footnote 1, page 10.



<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td>Glass Cones</td> <td>Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table>		Glass Cones	Steel Cones	Hole Volume			Hole Depth			
	Glass Cones	Steel Cones									
Hole Volume											
Hole Depth											
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Color:</b> Greenish-yellow</p>										
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Principal Uses:</b> (c) Ingredient of primer mix</p>										
	<p><b>Method of Loading:</b> Pressed                  Dead presses at about 42,000 psi</p>										
	<p><b>Loading Density: gm/cc</b>                  At 42,000 psi 1.75</p>										
	<p><b>Storage:</b></p> <p>Method</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None</p>										
	<p><u>Qualitative Solubilities at Room Temperature:</u></p> <table border="0"> <thead> <tr> <th><u>Solvent</u></th> <th><u>Solubility</u></th> </tr> </thead> <tbody> <tr> <td>Acetone</td> <td>Readily soluble</td> </tr> <tr> <td>Chloroform</td> <td>Moderately soluble</td> </tr> <tr> <td>Alcohol</td> <td>Sparingly soluble</td> </tr> <tr> <td>Water</td> <td>Insoluble</td> </tr> </tbody> </table> <p><u>Compatibility with Metals:</u>                  Wet: Does not attack iron, steel, copper or brass.</p> <p><u>Heat of:</u>                  Combustion, cal/gm (a) 2554</p> <p><u>Burning Rate:</u> (b)                  cm/sec 0.65</p>	<u>Solvent</u>	<u>Solubility</u>	Acetone	Readily soluble	Chloroform	Moderately soluble	Alcohol	Sparingly soluble	Water	Insoluble
<u>Solvent</u>	<u>Solubility</u>										
Acetone	Readily soluble										
Chloroform	Moderately soluble										
Alcohol	Sparingly soluble										
Water	Insoluble										

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<sup>o</sup>-150<sup>o</sup>C until no trinitro trichlorobenzene (melting point 187<sup>o</sup>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 triazido-benzene 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<sup>o</sup>C with decomposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:<sup>81</sup>

- (a) S. 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.

<sup>81</sup>See footnote 1, page 10.

Composition: % C 24.6 H 3.3 N 15.3 O 56.8  $  \begin{array}{c}  \text{CH ONO} \quad \text{CH}_2 \text{ONO} \quad \text{CH}_2 \text{ONO}_2 \\    \quad   \quad   \\  \text{O}_2 \text{NOCH}_2 \text{CCH}_2 \text{OCH}_2 \text{CCH}_2 \text{OCH}_2 \text{CCH}_2 \text{ONO}_2 \\    \quad   \quad   \\  \text{CH}_2 \text{ONO}_2 \quad \text{CH}_2 \text{ONO}_2 \quad \text{CH}_2 \text{ONO}_2 \\  \text{C/H Ratio} \quad 0.115  \end{array}  $	Molecular Weight: (C <sub>15</sub> H <sub>24</sub> N <sub>8</sub> O <sub>26</sub> ) 732
	Oxygen Balance: CO <sub>2</sub> % -35 CO % -2.2
	Density: gm/cc Crystal 1.58
	Melting Point: °C 82 to 84
	Freezing Point: °C
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 9 Sample Wt, mg 24	Boiling Point: °C
	Refractive Index, n <sub>20</sub> <sup>D</sup> n <sub>25</sub> <sup>D</sup> n <sub>30</sub> <sup>D</sup>
Friction Pendulum Test: Steel Shoe Unaffected Fiber Shoe Unaffected	Vacuum Stability Test: cc/40 Hrs, at 90°C ----- 100°C Pure 2.45 120°C Specially purified 1.94 135°C 150°C
Rifle Bullet Impact Test: Trials % Explosions Partial Burned Unaffected	200 Gram Bomb Sand Test: Sand, gm 58.9
Explosion Temperature: °C Seconds, 0.1 (no cap used) --- 1 --- 5 225 10 15 20	Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate ----- Lead Azide 0.30 Tetryl -----
	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	Trauzl Test, % TNT:
<b>Flammability Index:</b>	Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT
Hygroscopicity: %	Detonation Rate: Confinement None Condition Pressed Charge Diameter, in. 0.5 Density, gm/cc 1.56 Rate, meters/second 7650
Volatility:	

<p>Booster Sensitivity Test: Condition Tetryl, gm Wax, in. for 50% Detonation Wax, gm Density, gm/cc</p>	<p>Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (<math>\Delta H</math> kcal/mol) 23.1 Temperature Range, °C 215 to 250 Phase Liquid</p>
<p>Heat of: Combustion, cal/gm 2632 Explosion, cal/gm 1085 Gas Volume, cc/gm 762 Formation, cal/gm Fusion, cal/gm</p>	<p>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</p>
<p>Specific Heat: cal/gm/°C <u>Specific Impulse:</u> 1b-sec/lb (calculated) 240</p>	<p>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</p>
<p>Burning Rate: cm/sec</p>	
<p>Thermal Conductivity: col/sec/cm/°C</p>	
<p>Coefficient of Expansion: Linear, %/°C  Volume, %/°C</p>	
<p>Hardness, Mohs' Scale:</p>	
<p>Young's Modulus: E, dynes/cm<sup>2</sup> E, lb/inch<sup>2</sup> Density, gm/cc</p>	
<p>Compressive Strength: lb/inch<sup>2</sup></p>	
<p>Vapor Pressure: °C mm Mercury</p>	

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc                  Charge Wt, lb</p> <p><b>Total No. of Fragments:</b>                  For TNT                  For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="0"> <tr> <td></td> <td align="center">Glass Cones</td> <td align="center">Steel Cones</td> </tr> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </table> <hr/> <p><b>Color:</b> <span style="float: right;">White</span></p> <hr/> <p><b>Principal Uses:</b> High explosive and as possible plasticizer for nitrocellulose</p> <hr/> <p><b>Method of Loading:</b> <span style="float: right;">Cast or pressed</span></p> <hr/> <p><b>Loading Density: gm/cc</b>                  Pressed at 60,000 psi <span style="float: right;">1.565</span></p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth																																
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<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft                  At 25½ ft                  Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method <span style="float: right;">Dry</span></p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation <span style="float: right;">None</span></p>																																							
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Air, Confined:</b>                  Impulse</p> <p><b>Under Water:</b>                  Peak Pressure                  Impulse                  Energy</p> <p><b>Underground:</b>                  Peak Pressure                  Impulse                  Energy</p>	<p><b>Hygroscopicity, Gain or Loss in Wt. %:</b></p> <table border="1"> <thead> <tr> <th rowspan="2">Time, Hrs</th> <th colspan="3">% RH at 30°C</th> </tr> <tr> <th>40</th> <th>70</th> <th>90</th> </tr> </thead> <tbody> <tr> <td>24</td> <td align="center">-0.008</td> <td align="center">+0.01</td> <td align="center">+0.04</td> </tr> <tr> <td>48</td> <td align="center">-0.02</td> <td align="center">-0.01</td> <td align="center">+0.02</td> </tr> <tr> <td>144</td> <td align="center">-0.04</td> <td align="center">-0.03</td> <td align="center">-0.02</td> </tr> <tr> <td>192</td> <td align="center">-0.04</td> <td align="center">-0.02</td> <td align="center">-----</td> </tr> <tr> <td>216</td> <td align="center">-0.004</td> <td align="center">-0.01</td> <td align="center">+0.03</td> </tr> </tbody> </table> <p><b>Solubility:</b></p> <table border="0"> <tr> <td><u>Solvent</u></td> <td><u>Solubility</u></td> </tr> <tr> <td>Water</td> <td>Insoluble</td> </tr> <tr> <td>Alcohol</td> <td>Soluble</td> </tr> <tr> <td>Chloroform</td> <td>Soluble</td> </tr> <tr> <td>Acetone, hot</td> <td>Very soluble</td> </tr> <tr> <td>Benzene, hot</td> <td>Very soluble</td> </tr> </table>	Time, Hrs	% RH at 30°C			40	70	90	24	-0.008	+0.01	+0.04	48	-0.02	-0.01	+0.02	144	-0.04	-0.03	-0.02	192	-0.04	-0.02	-----	216	-0.004	-0.01	+0.03	<u>Solvent</u>	<u>Solubility</u>	Water	Insoluble	Alcohol	Soluble	Chloroform	Soluble	Acetone, hot	Very soluble	Benzene, hot	Very soluble
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	NTN	PETN	RDX	TPEON

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  $-25^{\circ}$  to  $0^{\circ}\text{C}$ . On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at  $0^{\circ}$  to  $5^{\circ}\text{C}$  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  $71^{\circ}$  to  $74^{\circ}\text{C}$ . 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  $0^{\circ}$  to  $10^{\circ}\text{C}$  was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).



References: <sup>82</sup>

- (a) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, The Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PAIR 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 PEIN 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.

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<sup>82</sup>See footnote 1, page 10.

Composition: % TNT 80 Aluminum 20  C/H Ratio	Molecular Weight: 81	
	Oxygen Balance:	
	CO, %	-77
	CO %	-38
	Density: gm/cc	Cast 1.72
Melting Point: °C		
Freezing Point: °C		
Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 85 Sample Wt 20 mg Picatinny Arsenal Apparatus, in, 13 Sample Wt, mg 16	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$	
$n_{30}^D$		
Friction Pendulum Test:	Vacuum Stability Test:	
Steel Shoe Unaffected	cc/40 Hrs, at 90°C	
Fiber Shoe Unaffected	100°C	0.1
Rifle Bullet Impact Test: Trials %	120°C	0.2
	135°C	--
	150°C	0.8
	200 Gram Bomb Sand Test: Sand, gm	
	Sensitivity to Initiation:	
	Minimum Detonating Charge, gm	
	Mercury Fulminate	
Lead Azide	0.20	
Tetryl	0.10	
15°C International Heat Test: % Loss in 48 Hrs	Ballistic Mortar, % TNT: (a) 124	
	Traurl Test, % TNT: (b) 125	
	Plate Dent Test: (c)	
00°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs	Method	B
	Condition	Cast
	Confined	no
	Density, gm/cc	1.75
flammability Index: 100	Brisance, % TNT 93	
	Detonation Rate:	
	Confinement	None None
	Condition	Cast Pressed
hygroscopicity: % 30°C, 90% RH 0.00	Charge Diameter, in,	1.0 1.0
	Density, gm/cc	1.71 1.72
Volatility:	Rate, meters/second 6475 6700	

<p>Booster Sensitivity test: (d)</p> <p>Condition Cast</p> <p>Tetryl, gm 100</p> <p>Wax, in. for 50% Detonation 0.58</p> <p>Wax, gm</p> <p>Density, gm/cc 1.75</p>	<p>Decomposition Equation:</p> <p>Oxygen, atoms/sec (Z/sec)</p> <p>Heat, kilocalorie/mole (AH kcal/mol)</p> <p>Temperature Range, °C</p> <p>Phase</p>																																		
<p>Heat of: (c)</p> <p>Combustion, cal/gm 4480</p> <p>Explosion, cal/gm 1770</p> <p>Gas Volume, cc/gm</p> <p>Formation, cal/gm</p> <p>Fusion, cal/gm</p>	<p>Armor Plate Impact test: (e)</p> <p>60 mm Mortar Projectile:</p> <p>50% Inert, Velocity, ft/sec 509 &gt; 1100</p> <p>Aluminum Fineness 100 12</p> <p>500-lb General Purpose Bombs:</p> <table border="1"> <thead> <tr> <th>Plate Thickness, inches</th> <th>Trials</th> <th>% Inert</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td></td> </tr> <tr> <td>1¼</td> <td>6</td> <td>100</td> </tr> <tr> <td>1½</td> <td>6</td> <td>33</td> </tr> <tr> <td>1¾</td> <td>0</td> <td></td> </tr> </tbody> </table>	Plate Thickness, inches	Trials	% Inert	1	0		1¼	6	100	1½	6	33	1¾	0																				
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1½	6	33																																	
1¾	0																																		
<p>Specific Heat: cal/gm/°C (b)</p> <p>At -5°C 0.23</p> <p>Density, gm/cc 1.74</p> <p>At 20°C 0.31</p>	<p>Bomb Drop test: (e)</p> <p>17, 2000-lb Semi-Armor-Piercing Bomb vs Concrete:</p> <p>Max Safe Drop, ft</p> <p>500-lb General Purpose Bomb vs Concrete:</p> <table border="1"> <thead> <tr> <th rowspan="2">Height, ft</th> <th colspan="2">Seal</th> </tr> <tr> <th>4,000</th> <th>5,000</th> </tr> </thead> <tbody> <tr> <td>Trials</td> <td>34</td> <td>14</td> </tr> <tr> <td>Unaffected</td> <td>32</td> <td>14</td> </tr> <tr> <td>Low Order</td> <td>0</td> <td>0</td> </tr> <tr> <td>High Order</td> <td>2</td> <td>0</td> </tr> </tbody> </table> <p>1000-lb General Purpose Bomb vs Concrete:</p> <table border="1"> <thead> <tr> <th rowspan="2">Height, ft</th> <th colspan="2">Seal</th> </tr> <tr> <th>5,000</th> <th></th> </tr> </thead> <tbody> <tr> <td>Trials</td> <td></td> <td>24</td> </tr> <tr> <td>Unaffected</td> <td></td> <td>23</td> </tr> <tr> <td>Low Order</td> <td></td> <td>0</td> </tr> <tr> <td>High Order</td> <td></td> <td>1</td> </tr> </tbody> </table>	Height, ft	Seal		4,000	5,000	Trials	34	14	Unaffected	32	14	Low Order	0	0	High Order	2	0	Height, ft	Seal		5,000		Trials		24	Unaffected		23	Low Order		0	High Order		1
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Trials		24																																	
Unaffected		23																																	
Low Order		0																																	
High Order		1																																	
<p>Burning Rate:</p> <p>cm/sec</p>																																			
<p>Thermal Conductivity: (b)</p> <p>cal/sec/cm/°C 11 × 10<sup>-4</sup></p> <p>Density, gm/cc 1.73</p>																																			
<p>Coefficient of Expansion:</p> <p>Linear, %/°C</p> <p>Volume, %/°C</p>																																			
<p>Hardness, Mohs' Scale:</p>																																			
<p>Young's Modulus: (b)</p> <p>E, dynes/cm<sup>2</sup> 6.67 × 10<sup>10</sup></p> <p>E, lb/inch<sup>2</sup> 0.97 × 10<sup>6</sup></p> <p>Density, gm/cc 1.72</p>																																			
<p>Compressive Strength: lb/inch<sup>2</sup> (b) 2340</p> <p>Density, gm/cc 1.75</p>																																			
<p>Vapor Pressure:</p> <p>°C mm Mercury</p>																																			

<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b>                  Density, gm/cc 1.71                  Charge Wt, lb 2.272</p> <p><b>Total No. of Fragments:</b>                  For TNT 703                  For Subject HE 616</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b>                  Density, gm/cc 1.73                  Charge Wt, lb 0.914</p> <p><b>Total No. of Fragments:</b>                  For TNT 514                  For Subject HE 485</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <table border="1"> <thead> <tr> <th></th> <th>Glass Cones</th> <th>Steel Cones</th> </tr> </thead> <tbody> <tr> <td>Hole Volume</td> <td></td> <td></td> </tr> <tr> <td>Hole Depth</td> <td></td> <td></td> </tr> </tbody> </table> <p><b>Color:</b> Gray</p> <p><b>Principal Uses:</b> CP bombs</p> <p><b>Method of Loading:</b> Cast</p> <p><b>Loading Density: gm/cc</b> 1.65-1.72</p>		Glass Cones	Steel Cones	Hole Volume			Hole Depth		
	Glass Cones	Steel Cones								
Hole Volume										
Hole Depth										
<p><b>Fragment Velocity: ft/sec</b>                  At 9 ft 2460                  At 25½ ft 2380                  Density, gm/cc 1.72</p>	<p><b>Storage:</b></p> <p><b>Method</b> Dry</p> <p><b>Hazard Class (Quantity-Distance)</b> Class 9</p> <p><b>Compatibility Group</b> Group I</p> <p><b>Exudation</b></p>									
<p><b>Bbst (Relative to TNT):</b> (f)</p> <p><b>Air:</b>                  Peak Pressure 110                  Impulse 115                  Energy 119</p> <p><b>Air, Confined:</b>                  Impulse 130</p> <p><b>Under Water:</b>                  Peak Pressure 105                  Impulse 118                  Energy 119</p> <p><b>Underground:</b>                  Peak Pressure 117                  Impulse 127                  Energy 136</p>	<p><b>Preparation:</b></p> <p>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.</p>									

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Escales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TNT/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decreased by additions of aluminum up to 40% (Ref j). For all practical purposes it is concluded that the addition of 18% to 20% aluminum to TNT improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TNT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TNT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:<sup>83</sup>

- (a) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part 111, 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, PAIR No. 1290, First Progress Report, 19 May 1943.
- (i) W. R. Tomlinson, Jr., Develop New High Explosive Filler for AP Shot, PAIR No. 1380, Second Progress Report, 12 January 1944.
- (j) L. S. Wise, Effect of Aluminum on the Rate of Detonation of TNT, PAIR No. 1550, 26 July 1945.
- (k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

<sup>83</sup>See footnote 1, page 10.

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

<u>0</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
1530	1693	1444	1635	1956	1737	2138
1560	2353				2127	
2010						

<b>Composition:</b> % HMX 70.0 Nitrocellulose (13.15% N) 15.0 Nitroglycerin 10.7 2-Nitrodiphenylamine 1.3 Triacetin 3.0  C/H Ratio	Molecular Weight:	281
	Oxygen Balance:	
	CO <sub>2</sub> %	-26
	CO %	-0.5
	Density: gm/cc	Pressed
	Melting Point: °C	
	Freezing Point: °C	
<b>Impact Sensitivity, 2 Kg Wt:</b> Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg	Boiling Point: °C	
	Refractive Index, $n_{20}^D$	
	$n_{25}^D$	
	$n_{30}^D$	
<b>Friction Pendulum Test:</b> Steel Shoe Unaffected Fiber Shoe Unaffected	<b>Vacuum Stability Test:</b> cc/40 Hrs, at 90°C ---- 100°C 1.29 120°C 29 hours 11+ 135°C 150°C	
<b>Rifle Bullet Impact test:</b> Trials % Explosions Partials Burned Unaffected	<b>200 Gram Bomb Sand Test:</b> Sand, gm 66.4	
<b>Explosion Temperature:</b> °C Seconds, 0.1 (no cap used) 1 5 10 15 20	<b>Sensitivity to Initiation:</b> Minimum Detonating Charge, gm Mercury Fulminate ---- Lead Azide 0.30 Tetryl ----	
	<b>Ballistic Mortar, % TNT:</b>	
	<b>Trauzl Test, % TNT:</b>	
	<b>Plate Dent Test:</b> Method Condition Confined Density, gm/cc Brisance, % TNT	
	<b>Detonation Rate:</b> Confinement Condition Charge Diameter, in. Density, gm/cc Rate, meters/second (calculated) 8500	
<b>75°C International Heat Test:</b> % Loss in 48 Hrs		
<b>90°C Heat Test:</b> % Loss, 1st 48 Hrs 0.28 % Loss, 2nd 48 Hrs 1.12 Explosion in 100 Hrs None		
<b>Flammability Index:</b>		
<b>Hygroscopicity: %</b>		
<b>Volatility:</b>		

\*See footnote on following page.





<p><b>Fragmentation Test:</b></p> <p><b>90 mm HE, M71 Projectile, Lot WC-91:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p> <p><b>3 inch HE, M42A1 Projectile, Lot KC-5:</b> Density, gm/cc Charge Wt, lb</p> <p><b>Total No. of Fragments:</b> For TNT For Subject HE</p>	<p><b>Shaped Charge Effectiveness, TNT = 100:</b></p> <p style="text-align: center;">Glass Cones    Steel Cones</p> <p>Hole Volume Hole Depth</p>
	<p><b>Color:</b> Orange</p>
	<p><b>Principal Uses:</b> High mechanical strength machinable explosive</p>
	<p><b>Method of Loading:</b> Pressed</p>
	<p><b>Loading Density:</b> gm/cc At 6,700 psi 1.72</p>
<p><b>Fragment Velocity:</b> ft/sec At 9 ft At 25½ ft Density, gm/cc</p>	<p><b>Storage:</b></p> <p>Method Dry</p> <p>Hazard Class (Quantity-Distance)</p> <p>Compatibility Group</p> <p>Exudation None Machinability Excellent</p>
<p><b>Blast (Relative to TNT):</b></p> <p><b>Air:</b> Peak Pressure Impulse Energy</p> <p><b>Air, Confined:</b> Impulse</p> <p><b>Under Water:</b> Peak Pressure Impulse Energy</p> <p><b>Underground:</b> Peak Pressure Impulse Energy</p>	

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 determine the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference: <sup>84</sup>

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


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<sup>84</sup>See footnote 1, page 10.

(AMCRD-TV)

FOR THE COMMANDER:

OFFICIAL:

  
P. R. HORNE  
Colonel, GS  
Chief, HQ Admin Mgt Ofc

CHARLES T. HORNER, JR.  
Major General, USA  
Chief of Staff

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No. AMCP 706-	Title	No. AMCP 706-	Title
100	*Design Guidance for Producibility	201	*Rotorcraft Engineering, Part One, Preliminary Design
104	*Value Engineering	202	*Rotorcraft Engineering, Part Two, Detail Design
106	Elements of Armament Engineering, Part One, Sources of Energy	203	*Rotorcraft Engineering, Part Three, Qualification Assurance
107	Elements of Armament Engineering, Part Two, Ballistics	205	*Timing Systems and Components
108	Elements of Armament Engineering, Part Three, Weapon Systems and Components	210	Fuzes
109	*Tables of the Cumulative Binomial Probabilities	211(C)	Fuzes, Proximity, Electrical, Part One (U)
110	Experimental Statistics, Section 1, Basic Concepts and Analysis of Measurement Data	212(S)	Fuzes, Proximity, Electrical, Part Two (U)
111	Experimental Statistics, Section 2, Analysis of Enumerative and Classificatory Data	213(S)	Fuzes, Proximity, Electrical, Part Three (U)
112	Experimental Statistics, Section 3, Planning and Analysis of Comparative Experiments	214(S)	Fuzes, Proximity, Electrical, Part Four (U)
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120	*Criteria for Environmental Control of Mobile Systems	241(S)	*Land Mines (U)
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125	Electrical Wire and Cable	245(C)	Ammunition, Section 2, Design for Terminal Effects (U)
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139	Servomechanisms, Section 4, Power Elements and System Design	270	Propellant Actuated Devices
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150	Interior Ballistics of Guns	282	+Propulsion and Propellants (REPLACED BY -285)
160(S)	Elements of Terminal Ballistics, Part One, Kill Mechanisms and Vulnerability (U)	283	Aerodynamics
161(S)	Elements of Terminal Ballistics, Part Two, Collection and Analysis of Data Concerning Targets (U)	284(C)	Trajectories (U)
162(SRD)	Elements of Terminal Ballistics, Part Three, Application to Missile and Space Targets (U)	285	Elements of Aircraft and Missile Propulsion (REPLACES -282)
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