Properties of Selected High Explosives
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ABSTRACT

This paper was presented at the 27th International Pyrotechnics Seminar, 16 – 21 July 2000 in Grand Junction, CO., and is an update on the PEP-I Wall Chart that was presented at the Eighteenth International Pyrotechnics Seminar, July 1992, at Breckenridge, CO. The descriptive text has not changed. The Wall Chart has been corrected and updated with chemical symbols of the explosives. An Appendix of Engineering Tools has been added.

There is a need in the pyrotechnic, explosive, and propellant engineering and scientific community to compile the energetic material property and characteristic data for a single point reference. The objective of this paper is to fulfill that need for the properties and characteristics of selected high explosives of interest to the defense and aerospace industry. The information is collected from published literature and compiled for easy access in data sheet and wall chart format. Members of the engineering and scientific community of all disciplines are invited for input to the development of the knowledge base that is represented. Equally important to presenting the data is to identify the source as reference, which is listed at the end of this paper. This paper is updated periodically to include recent changes.

Explosives referenced in MIL-STD-1316 are discussed together with common secondary explosives:

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All the 'Compositions', and PBXN-6, and CYCLOTOL are RDX based; PBXN-5, and OCTOL is HMX based; XTX-8003 is PETN based; The 'TOLs' (CYCLOTOL and OCTOL) contain TNT as a second ingredient. TETRYL is no longer manufactured and is being phased out as a MIL-STD-1316 explosive. DATB and TATB are explosives with limited published literature found to be available.

Explosive properties and characteristics of interest are discussed:

- Chemical Composition
- Density
- Crystal Hardness
- Autoignition
- Critical Temperature
- Melt Point
- Decomposition Temperature
- Gas Volume
- Detonation Pressure
- VOD Formulae
- Velocity Of Detonation
- Temperature of Detonation
- Vacuum Stability
- Hygroscopicity
- Thermal Stability
- Heat of Combustion
- Heat of Reaction
- Heat of Formation
- Heat of Products of Detonation
- Shock Sensitivity Threshold
- Laser Initiation Threshold
- TNT Equivalency
- Brisance
- Impact sensitivity
- Friction Sensitivity
- Explosive Specification
RESULT
This paper supports the first of the proposed Wall Chart series "International Pyrotechnics Society Properties of Selected High Explosives: "PEP-I" [42]. The IPS "PEP-I" Wall Chart was presented at the poster session of this seminar.

CONCLUSION (disclaimer)
Although much work has been done to identify the properties and characteristics of PEP, the author has found many ambiguities in the technical literature which do not satisfy scientific inquiry. It is hoped that with the help of the PEP community there will be enough interest to fill the gaps in the scientific discipline. The literature referenced at the end of this document also includes literature not quoted in this paper but is of interest for further inquiry.

INTRODUCTION
To be classified as an explosive, a material must.

1. Satisfy basic conditions with respect to its rate of chemical reaction.
2. The reaction must not take place until a suitable initiation stimulus is applied.
3. The reaction must be violent; there must be complete or nearly complete conversion into gaseous products.
4. The reaction must be exothermic.
5. The reaction must be self-sustaining without requirement for an external oxygen source or energy, such as heat, except that necessary to initiate the reaction.

The pressure produced by an explosion is due to the gases evolved and is dependent on their volume and temperature. The work potential of an explosive depends primarily upon the quantity of heat given off in the reaction.

Classes of Explosives
According to their chemical reaction rate and resulting output characteristics, explosives are classified as low explosives and high explosives. There is no sharp line of demarcation between the two classes, and within each class there may be explosives of considerably different performance, since they are grouped only according to reaction rate. Low explosives, which deflagrate (burn) rather than detonate and propagate at velocities 1,000 meters per second (m/s) and less, include the propellants, pyrotechnics and initiating or primer explosives. Examples are nitrocellulose, double base powder, smokeless powder, black powder, cordite and the metal-oxidizer mixtures.

Explosives which detonate and propagate at velocities greater than 1000 m/s, are high explosives and include the secondary explosives RDX, HMX, HNS, DIPAM, Tetryl, DATB, TATB, PETN, TNT, most of their compositions, and the primary explosives lead azide and lead styphnate. This paper will not discuss the primary explosives.

DEFINITIONS
It is necessary for comprehension of further discussion to define terms as they apply in this document.

Properties
Properties of explosives reported herein are measurable physical attributes typical of a single crystal of an explosive material. Chemical Composition, Density, Crystal Hardness, Auto Ignition Temperature, Critical Temperature, Melt Point, Decomposition Temperature, Gas Volume, Temperature of Detonation, Vacuum Stability, Hygroscopicity, Heat of Combustion, Heat of Reaction, Heat of Formation, Heat of Products of Detonation are categorized as properties of an explosive. The term properties shall mean to include explosive characteristics in this manuscript.
**Characteristics**
The characteristic of an explosive is an attribute measured as a performance value after or during the chemical reaction. Detonation Velocity, Detonation Pressure, Velocity of Detonation Formulae, Shock Sensitivity, Laser Initiation Sensitivity, TNT Equivalency, Brisance, Impact and Friction are categorized as characteristics.

**Explosives** (36)
Compositions or mixtures of materials, which are capable of undergoing exothermic chemical reaction at extremely, fast rates to produce gaseous and/or solid reaction products at high pressure and temperature.

**High Explosives** (36)
High explosives are those in which the chemical reaction, which has been initiated by heat or shock, will propagate at detonation velocities. The result simulates an instantaneous release of the products of explosion. This is termed detonation, or high-order explosion, to differentiate it from low-order explosions, such as the rapid combustion of pyrotechnics and propellants. The products of combustion of high explosives produce extremely high temperatures (e.g. RDX 3600°K (8)), large quantities of gas and some solids. High explosives can be controlled to deflagrate and as such can be used as propellants.

**Detonation** (20)
If the propagation velocity of the reaction wave is greater than the velocity of sound in the unreacted material, the wave is said to be a detonation wave and its velocity of propagation is called detonation velocity. The mechanism of detonation is not definitely known, although various hypotheses have been advanced to account for the phenomenon. It is generally agreed that the energy responsible for the extremely rapid decomposition is propagated through an explosive in the form of a mechanical or shock wave, somewhat similar to a sound wave. The wave may be initiated by mechanical or thermal shock sufficient to cause hydrodynamic compression of the first increment or layer of the charge. The energy liberated reinforces the applied shock so that a self-sustaining shock wave is transmitted at high velocity throughout the explosive preceding the reaction zone. Thus, high explosives are characterized essentially by their rapid rate of decomposition when initiated, and by the resultant high rate of energy release.

The speed of the detonation wave, or the velocity of detonation, varies considerably in the various explosives, and may vary in a given explosive under different conditions. For example, under similar conditions of confinement, trinitrotoluene (TNT) and nitroglycerin detonate at rates of 6,800 and 8,400 meters per second, respectively. The degree of confinement will affect these rates somewhat, but not to the same extent as in the low explosives.

**Low Explosives** (36)
There are two categories of low explosives, pyrotechnics and propellants. Both have chemical reactions, which deflagrate.

**Deflagration** (36)
If the propagation velocity is less than the velocity of sound in the unreacted material, the reaction is said to be a deflagration and its velocity of propagation is referred to as burn rate.

**Pyrotechnics** (36)
A pyrotechnic is a mixture of ingredients of fuel and oxidant (e.g. BKNO₃) producing a chemical reaction occurring at a burn rate typically less than 1000 meters per sec (m/s). The reaction does not reach sonic velocities in the unreacted material; therefore, does not produce a detonation. However, under very specific conditions; some pyrotechnics can be made to detonate. The products of combustion primarily produce very hot burning solid particles leaving considerable solid residue behind. There is very little gas generated by pyrotechnics. Pyrotechnics are generally used to produce heat and color in the form of light and smoke.
Propellants (36)
A propellant can be a compound or a mixture of a pyrotechnic material and high explosive (e.g. Ammonium Perchlorate and HMX) producing a chemical reaction (burn rate) typically less than 1000 m/s, and in rocket propellants often measured in centimeters per second. The reaction does not reach sonic velocities in the unreacted material therefore, does not produce a detonation. Propellants are designed for controlled burning rates producing large quantities of gas at elevated temperature and pressure. However, under very specific conditions, propellants can be made to detonate.
PROPERTIES & CHARACTERISTICS

Density (36)
Density is the mass per unit volume expressed in units of grams per cubic centimeter. Density is the explosive property that is used to predict velocity of detonation (VOD). The VOD varies in direct proportion to density for most explosives. Density values also affect sensitivity of a given explosive; an explosive is more sensitive in the unconsolidated state.

Theoretical Maximum Density (TMD) — TMD is mass per unit volume of a single crystal of the explosive. TMD is sometimes referred to as the ‘Crystal Density’.

Bulk Density — The bulk density of an explosive is the mass per unit of volume as manufactured, which includes voids. A sample specimen consists of an explosive loosely poured into a graduated cylinder. The cylinder is filled with the specimen sample by gravity feed to the 100-ml level. The cylinder is then tapped on the side a fixed number of times (typically 5 times) to eliminate particle-bridging creating large voids. This value is useful in determining burn rate of the bulk material during certain manufacturing processes.

Loaded Density — The loaded density value is the mass per unit volume relative to the loaded end item. Loading density is expressed in units of grams per cubic centimeter at pounds per square inch. Loaded density is the design parameter that is used to predict the velocity of detonation (VOD). As the loading density of an explosive increases, the VOD also increases up to about 98% TMD. At loaded density above 98% TMD, there is a condition which will cause the initiation threshold to drastically increase; this is referred to as “Dead Pressing”.

Cast Density (36) — The ability of an explosive to be melt-poured into its container is known as casting. The cast density of an explosive is measured after the explosive has cooled to a solid at ambient conditions. A casting explosive has a low melt temperature such as TNT, a binary explosive (Cyclotol, RDX/TNT), or a mixture of an explosive held in suspension by a melt carrier (Composition A-3, RDX/Wax). Casting is performed under vacuum when reduction of voids is a concern.

Crystal Hardness (30) — Mohs’ Hardness Scale — Mohs’ Hardness Scale is mainly applied to nonmetallic elements and minerals. It is the standard used to determine the relative hardness of an explosive. In this hardness scale there are ten degrees or steps, each designated by a mineral, the difference in hardness of the different steps being determined by the fact that any member in the series will scratch any of the preceding members. This scale is as follows:

These minerals, arbitrarily selected as standards, are successively harder from talc, the softest of all minerals, to diamond, the hardest. This scale, which is now universally used for non-metallic minerals, is, however, not applied to metals.

Autoignition Temperature (36) — The Autoignition Temperature of an explosive is the temperature at which a material will react when the specimen begins to liberate heat due to self-heating. This is accomplished by placing a sample in an automatically controlled environment. Temperature is increased at a controlled rate until the sample material begins to liberate heat. When self-heating occurs, no additional oven temperature is allowed to enter the sample. The reported value is usually less than the value reported for decomposition temperature. The autoignition temperature is a critical value when comparing various explosives. The values reported may vary as a function of the type of oven used, or control method of the oven. The rate of heat applied by the oven should be less than 0.1° C per minute when self-heating occurs. Autoignition temperature may be determined by calculation from decomposition temperature results obtained by a Differential Scanning Calorimeter (DSC) or a Differential Thermal Analyzer (DTA).
Critical Temperature (10, 20, 32) — The critical temperature using the Los Alamos Scientific Laboratories (LASL) method is based on a time-to-explosion test. The explosive sample is pressed into a blasting cap shell and covered with a skirted plug. The sample is then dropped into a preheated liquid metal bath, and the time to explosion is measured as the time to the sound created by rupture of the shell or unseating of the plug. The critical temperature may be defined as the minimum temperature at which a specimen of a specified size, shape, and boundary constraint can be heated without undergoing thermal runaway or explosion. Lawrence Livermore National Laboratory (LLNL) defines critical temperature as the temperature at which a high explosive of a given configuration self heats to explosion.

Melt Point (36) — The Melt Point of an explosive is the temperature at which a phase transition occurs from solid to liquid. The structure changes from an ordered crystalline array of molecules and atoms to a less ordered configuration. To achieve this phase-change, a certain amount of heat must be added which goes entirely into changing the phase without raising the temperature.

Explosives, which do not melt, are suspended as in ‘compositions’ with a wax or other compatible melt carrier for casting.

Decomposition Temperature (36) — Decomposition temperature is the temperature at which exothermic and endothermic reactions occur in an explosive when it is heated. The test measures the temperature difference between the explosive and a thermally inert reference material as both are heated at a constant rate of increase in temperature. A DSC or DTA detects exothermic or endothermic changes that occur in the explosive while it is being heated. These changes may be related to dehydration, decomposition, crystalline transition, melting, boiling, vaporization, polymerization, oxidation or reduction. The temperature at which the maximum differential between the sample and the reference temperature occurs before self-heating is the reported decomposition temperature value.

Gas Volume (20) — Gas volume of a specimen sample is obtained in a manner similar to heat of combustion, except that the reaction takes place in one atmosphere of air in the standard calorimeter bomb rather than in oxygen or an inert atmosphere. The sample is ignited and temperature and pressure measurements are obtained; the gas volume of the noncompressible gases is calculated by standard means, and the results are given in milliliter per gram (ml/g). The transducer will also provide a rate of change from which specific pressure time values are obtained. These results, such as peak pressure and pressure rate of rise, are reported as output characteristics.

The amount of gas liberated (gas volume) is significant in determining other characteristics of a given explosive. Generally, pyrotechnic mixtures are not as gaseous as propellants or explosives. However, those mixtures, which have liberated quantities of gas greater than 50 ml/g have a tendency to have a TNT equivalency of greater than 10%. Gas volume determination is quite useful in the determining the power of an explosive for design considerations.

Detonation Pressure (20) — Detonation pressure of an explosive is that pressure, expressed in kilobars (kbars), at the detonation front of the chemical reaction zone. The detonation pressure of a particular explosive is a function of its density.

Velocity of Detonation Formulae (20) — The formulae for measuring VOD in general is accurately represented by constants characteristic of an explosive. The constants are determined from empirical testing. Some explosives have a critical radius, which is included in the calculation.
Velocity Of Detonation \(^{(10, \ 20)}\) — Velocity of Detonation (VOD) can be determined in any of several ways: the choice of a method probably depends more on the availability of equipment and well tested procedures than on any inherent advantage of a given method.

Chronographic Method — The chronographic method is widely used. This method depends on the closing of switches either by the conduction of hot gases between two electrodes or by the forcing together of two electrodes by the pressure induced by the detonation. Precision of the measurements depends on the number of switches or pins that is used on the charge and on the precision of the equipment.

Electronic Method — Another method, which is also entirely electronic, depends on embedding a resistance wire in the explosive. A constant current is maintained in the resistance wire and the return path, which may be a nearby embedded copper wire, a wire or foil on the surface of the charge, or a metal case if the charge is confined. The voltage across the resistance wire is recorded on an oscilloscope. This voltage decreases as the detonation moves along the wire and effectively shortens the wire. This method gives, in effect, the instantaneous position of the detonation front so that the slope of the trace on the record from the oscilloscope is proportional to the detonation velocity. A closely related technique uses a resistance wire, which is wound on an insulated wire or other conducting core.

These methods are not recommended for pressed charges. The precision of either version of the resistance technique depends on the quality of the charges, the precision of making the probes, and the precision of the electronics. For smaller diameter charges, the probes and wires may perturb the detonation front so that a true value of the detonation velocity cannot be obtained.

Optical Method — A commonly used optical method makes use of the streak or smear camera to record the instantaneous position of the detonation front. Because the record gives the instantaneous location of the detonation front, the slope of the streak is proportional to the velocity. Simple data reduction techniques can be used for the application discussed here. The traces are straight so that after digitizing, the data is fitted with a linear relation, the coefficient of the time being the velocity of the detonation. This method can be made to give precise results if sufficient care is taken in preparing the charges and in arranging the experiment.

Temperature of Detonation \(^{(10, \ 36)}\) — Temperature of Detonation is the temperature of the reaction during the Chapman-Jouguet condition (detonation). The temperature is determined by measurement of relative light intensity at two different wavelengths. However, luminosity is dependent on the fourth power of temperature and a small variation in experimental conditions can cause a substantial change in luminosity and indicated temperature.
STABILITY TESTS
Stability tests determine if a hazardous material will remain safe and retain its properties during some specified period of storage. Stability tests may be distinguished from other tests by: (1) the manner in which the stimulus is applied, (2) the rate it is applied, (3) the non-destructive nature of the test, and (4) the objective of the expected results. Usually, in stability testing the stimulus is applied for a longer duration and when heat is applied, the temperatures are below ignition levels of the suspect materials. In some cases there are no stimuli applied; instead long term storage is observed under a certain set of conditions. The expected results are not initiation, but rather changes in weight, volume of gases liberated, discoloration, evolution of oxides, and its ability to function properly after prolonged storage conditions.

Stability tests, in general, are designed to be applicable to one type of material (either: pyrotechnics, explosives, or propellants) and are not always suitable for all classes.

Because stability testing is time-consuming, it is often desirable to subject the material to conditions, which are more severe than those normally encountered during prolonged periods of storage. Specifically, two environmental factors can influence the stability of a given explosive: (1) humidity and (2) temperature. The latter receives the most attention in determining the stability of a material. In practice, the specimen material is subjected to a higher temperature than those normally encountered, and ultimately the material is tested to verify that it functions as intended at the completion of the elevated temperature study.

Vacuum Stability (20)
Vacuum Stability Test — A temperature of 100° or 120°C generally is employed for 40 or 48 hours on a sample of dried explosive. The system is evacuated until the pressure is reduced to about five millimeters of mercury. If an excessive amount of gas (11 + milliliters/gram) is not evolved in less time, heating is continued for 40 or 48 hours. The vacuum stability test yields reproducible values; and, when an explosive is subjected to this test at two or more temperatures, a rather complete picture of its chemical stability is obtainable. In some cases, tests at two or more temperatures are required to bring out significant differences in stability between explosives, but a test at 100°C is sufficient to establish the order of stability of an explosive. The vacuum stability test has been found suitable for determining the reactivity of explosives with each other or nonexplosive materials. This is accomplished by making a vacuum stability test of the explosive and determining if the gas liberated is significantly greater than the sum of the volumes liberated by the two materials when tested separately. When used for this purpose, the test generally is made at 100°C.

Hygroscopicity (7, 20, 36)
Hygroscopicity is the determination of the amount of moisture that a given sample material will absorb in a given period under varying conditions. The sample, if solid, is prepared by sieving through a 50-mesh screen and onto a 100-mesh screen. The values obtained under this test method are usually reported at 95% and 50% relative humidity values. The ability of a sample to absorb moisture does not necessarily negate its use in an end item. The addition of binder and waterproofing agents may be used to improve performance in this area. Sealing of the end item for storage will also reduce the amount of moisture that a given explosive can absorb. The values obtained in the hygroscopicity tests are usually obtained on bulk mixtures. This value would be highly significant for manufacturing processes where temperature and humidity conditions can be maintained during blending and filling operations. A temperature change (greater than 10° C) would not necessarily have any effect on a sealed end item if proper environmental conditioning occurred during manufacturing. Geometric parameters need to be considered when loading into an end item for long-term storage and ultimate use.

Values of less than 2% weight increase at 50% relative humidity are considered relatively good; whereas, any value greater than 2% would be fair. Values in excess of 10% weight increase at 90% relative humidity are generally considered to be poor.
Thermal Stability (20)
Samples are subjected to elevated temperatures to permit the observance of characteristic tendencies to detonate, ignite, decompose, or to undergo a change in configuration under adverse storage conditions. The sample is placed in an explosion-proof oven maintained at a predetermined temperature for a period of time (typically 48 hours). The temperature of the oven and of the explosive is continuously monitored throughout the test period. Observations recorded include whether the test specimen exploded, ignited, and/or underwent a change in configuration, such as a weight loss or change in color.

The results from this test aid in the determination of the overall classification of a bulk material. A 1% to 2% moisture loss is not considered a significant change in weight or configuration.

Heat of Combustion (20)
The heat of combustion is the gross heat in terms of calories per gram or kilocalories per mole of the explosive. The gross heat of combustion is measured by igniting samples of an explosive in an oxygen-filled (5 atmospheres) standard calorimeter bomb submerged in water, and then recording the rise in water temperature.

The heat of combustion of a pyrotechnic mixture gives an indication of heat liberation potential and explosive power potential.

Heat of Reaction (20)
The gross heat of reaction in terms of calories per gram is determined in a similar manner to the gross heat of combustion, except that the 1 to 2 g sample of explosive is burned in an inert atmosphere (nitrogen) in the same standard bomb calorimeter. Heat of reaction may be calculated using enthalpy data when the reaction products are known or assumed.

Heat of Formation (20)
The Heat of Formation refers to the enthalpy of the reaction. The sign convention is such that the heat of formation is negative when the reaction is exothermic and positive when the reaction is endothermic. The units are measured in kilocalories per mole.

Heat Of Products of Detonation (10)
The Heat of Products of Detonation is the energy release at the Chapman-Jouguet (C-J) condition, and refers to the change in enthalpy and is always a negative value. Experimental values vary with density and confinement. The effective energy developed by an explosive is always less than the assumed thermodynamic energy. The reported values are expressed in both the liquid (L) and gas (G) test condition.

Shock Sensitivity Threshold (36)
Many high explosives are not readily detonated by direct application of heat or by mechanical blow, but require a shock produced by chemical reaction of the explosive itself. These are called secondary high explosives.

Shock Initiation — To shock initiate an explosive, it is necessary to send a shock into the explosive by the application of mechanical force. The initiation of the explosive is a function both of the intensity of the force and rate of application to a unit of area. Initiation of an explosive by shock is expressed in terms of shock sensitivity at a 50% threshold. A sensitive explosive may withstand a very great force applied slowly over a large surface area as in a press, but detonate violently when the same force is applied suddenly or to a much smaller surface area. Violent detonation may also occur with a suddenly applied force, such as a sharp hammer blow.

Shock initiation is measured in force per unit area (pressure) with the kilobar as the base unit and it is assumed, for practicality, that the force is applied instantaneously. Duration of force applied is also a parameter but often is omitted in the literature.
Flyer Plate (33) — Impact pressure on unreacted explosives is determined by a flyer plate device used to provide an input stimulus. The flyer plate is driven by a capacitor electrical discharge into a metal bridge foil which, when vaporized by the high current, creates tremendous pressure against a Kapton sheet supported by a barrel. The Kapton sheet shears at the barrel’s sharp inside diameter edges creating a disc (flyer plate). The flyer plate is accelerated down the barrel to impact the test explosive. The flyer velocity determines the impact pressure amplitude. The flyer thickness determines the duration of the impact pulse. When the flyer shock impedance is less than that of the explosive, the pulse is rectangular. Flyer velocity is predetermined through calibration of voltage to the capacitor(s), measuring the flyer velocity at capacitor discharge using LASER interferometry reflection off the surface of the accelerating flyer plate. Flyer velocity is not measured during actual tests.

Gap Tests — The gap test is used to measure the sensitivity of an explosive material to shock. The test results are reported as the thickness of an inert spacer material that has a 50 percent probability of allowing detonation when placed between the test explosive and a standard detonating charge. In general, the larger the spacer gap, the more shock-sensitive is the explosive under test. The values, however, depend on test size and geometry and on the sample (the particular lot, its method of preparation, its density, and percent voids). Gap test results, therefore, are only approximate indications of relative shock sensitivity. Tests have been developed covering a wide range of sensitivities for solid and liquid explosives at Los Alamos National Laboratory (LANL), Naval Surface Weapons Center (NSWC), Mason & Hanger-Silas Mason Co. Inc., Pantex Plant (PX), and Stanford Research Institute (SRI). There are many gap test geometries to be considered when making an explosive evaluation. Validity of this test as a measure of degree of hazard associated with an explosive is questionable.

LASER Initiation Threshold (36)
LASER Initiation Threshold is produced by collimating and then focusing light waves and is a function of the amplitude of the wavelength of the light applied to a unit area. Laser initiation is measured in units of energy per unit area per time. EXAMPLE: Joules per square centimeter per second (J/cm²/sec). The LASER collimated beam frequency and area of incidence on the explosive for a particular experimental test is very important but is not always reported in the literature.

TNT Equivalency (High Explosive Equivalency) (7)
The TNT Equivalency determines the ratio of the amount of energy released in a detonation reaction of a sample explosive material to the amount of energy released by TNT under the same conditions. Following are instruments for TNT comparative determinations of the performance of different explosives.

Trauzel TNT Equivalency (6) — Ten grams of the explosive sample is placed into a soft lead block (200-mm diameter by 200 mm long) borehole (25mm diameter by 125 mm deep). The remaining volume is filled with quartz sand of standard grain size. The explosive is detonated and the increased volume of the borehole is measured with water. The original volume (61 cc) is deducted from the result, recorded and is compared to a TNT (sample of the same weight) volume. Similar tests have been performed in foamed plastic.

Ballistic Mortar TNT Equivalency (6) — A heavy, short-barreled mortar is suspended on a ten-foot pendulum rod. A ten-gram explosive sample is placed in the mortar cavity, a snugly fitting solid steel projectile is inserted over the explosive, the explosive is detonated and the length of arc swing of the mortar is measured. The base standard is a recoil measurement taken of the mortar arc swing that is produced when 10 grams of TNT drives the projectile out the muzzle. Samples of test explosives are subjected to the same test and the results are recorded as the relative percent of the TNT arc swing standard.

Pendulum TNT Equivalency (36) — A weight is suspended on a pendulum, an explosive sample propels a projectile to impact the weight causing the pendulum to swing in an arc. The kinetic energy of the projectile is then calculated from the potential energy of the projectile plus the arc length of the weight at the top of the arc swing. This method is often used in measuring output of explosive devices such as thrusters, piston actuators, etc.)
Brisance (7)
The term brisance refers to that quality or property of a high explosive evidenced by its capacity, upon detonation, to shatter any medium confining it. Brisance is the destructive fragmentation effect of an explosive detonation on its immediate vicinity. This property is different from that of the strength of an explosive; brisance depends greatly upon the rapidity of the reaction (density, VOD, specific energy); whereas, explosive strength depends upon the quantity of gas evolved and the heat given off.

Sand Test — A practical method of measuring brisance is the sand crush test, in which a measured sample of explosive is detonated in sand (of 30 mesh grain size), and the shattering effect on the grains of sand is evaluated by sieving after for change in the sand grain size.

The sand test is also used to determine TNT equivalency.

Dent Test — The depth of dent (deformation) from the explosion of an explosive sample is measured in a steel (or other base standard material) block. This test is a comparative test to create a standard criterion for detonating devices. The explosive is normally loaded in its end item configuration such as detonator caps, explosive end tips, linear shaped charge, etc.

The dent test is also used to determine TNT equivalency.

Gurney Constant (39) — The Gurney constant, the square root of 2E, is used to predict the average velocity of fragments produced by the detonation of explosives in contact with metals. The value of this constant may vary as much as 20% for a given explosive. The Gurney method to determine fragment velocities is based on the thermochemistry of the explosive. Gurney described E as an energy term, which was that portion of the chemical energy of the explosive that contributed to the kinetic energy of the fragment. This energy term may be more accurately correlated with the internal energy of formation than with the maximum energy available.

Fragment Velocity (40) — Average fragment velocities are predicted using the Gurney Constant. Values are given in meters per second at the explosive density.
SENSITIVITY TESTS

Sensitivity tests determine the minimum susceptibility of a given material to react to an externally applied energy. Sensitivity tests are abstract in view of the fact that they do not necessarily apply to output energies or application. In each case, the test is designed for a given set of externally applied energy sources to the system. The reaction may be a rapid output and the analysis may be qualitative or quantitative. Sensitivity tests do not stand alone in establishing safety criteria and parameters; rather, they determine at what energy levels a given material will react.

Impact Sensitivity (5)
Impact sensitivity determines the minimum energy at which a falling weight will cause a sample explosive material under total confinement to react violently.

There are four devices used to measure impact sensitivity, (1) Bureau of Explosive Apparatus (BoE), (2) Bureau of Mines Apparatus (BoM), (3) Picatinny Arsenal Apparatus (PA), and (4) the Explosive Research Laboratory Apparatus (ERL).

Supplementary Note:
The following discussion is relevant to the BoM and PA. Sensitivity to impact is expressed as the minimum height of fall of a given weight required to cause at least one explosion in 10 trials, or the minimum height of fall of a given weight to cause explosions in 50 percent of the trials. In such tests. The explosive is sieved so as to pass through a No. 50 United States Standard (USS) sieve and be retained on a No. 100 USS sieve. In carrying out the PA test, a steel die cup is filled with the explosive, covered with a brass cover, surmounted with a steel vented plug, placed in a positioned anvil, and subjected to the impact of a weight falling from a predetermined height. The minimum height, in inches, or centimeters, required for explosion is found after repeated trials. In making the test with the BoM apparatus, 0.02 gram of the sample is spread uniformly on a hard steel block, over a circular area one centimeter in diameter. A hard steel tip of that diameter, imbedded in a steel plunger, is lowered so as to rest on the explosive and turned gently so as to ensure uniform distribution and compression of the explosive. The plunger then is subjected to the impact of a weight falling from a predetermined height. When the minimum height required for explosion is found after repeated trials, this is expressed in centimeters. The PA apparatus can be used for testing explosives having a very wide range of sensitivity, but the BoM apparatus cannot cause the explosion of the most insensitive explosives and can be used only for testing explosives no less sensitive than TNT. The PA apparatus can be used for testing solid or liquid explosives. The test with the BoM apparatus can be modified so as to be applicable to liquid explosives. This is accomplished by using 0.007 to 0.002 gram (one drop) of the explosive absorbed in a disk of dry filter paper 9.5 millimeters in diameter.

Bureau of Explosives (BoE) (5)
A series of twenty tests is performed to determine the sensitivity of the sample material to mechanical shock (impact). A 10-mg sample is placed in the test cup. A 2kg test weight is dropped from a height, of 25.4-cm (10 in.) striking the sample.

The results of the 20 tests per sample, 10 at 9.5 cm (3 3/4 in) drop height and 10 at 25.4 cm (10 in) drop height, are reported as the number of trials exhibiting a reaction (decomposition, deflagration, detonation) and no reaction.

Bureau of Mines (BoM) (5)
A 20-mg sample is placed between two flat, parallel hardened (C63 ±2) steel surfaces. The 2kg weight is raised to the desired height and allowed to fall upon the sample. The impact value is the minimum height at which at least one of 10 trials results in an explosion.
Picatinny Arsenal (PA) \(^{(5)}\)
A sample material is passed through a No. 50 USS sieve and retained on a No. 100 USS sieve. Ten previously weighed die cups are filled with the sample specimen and the excess is removed with a wooden or plastic spatula. The die cups are then reweighed and the average weight of the material in each cup recorded. A brass cover is placed over each loaded die cup and pressed down by means of a small arbor press so that the cover is in contact with the top rim of the die cup. The loaded die cup is placed in the anvil. A 1 or 2 kg hammer is allowed to fall upon the sample. The up-down staircase method is used to determine the minimum height at which impact of the falling weight causes the sample material to explode in one of 10 trials.

Explosive Research Laboratory (ERL) \(^{(5, 20)}\)
The ERL impact test consists of a free-falling weight, (2.5 or 5 kg) tooling to hold the explosive sample. The sample to be tested is dried, usually under vacuum, and loaded into a dimple in the center of a sheet of garnet paper for testing with Tool Type 12 (Tool Type 12B is without the garnet paper). The ERL apparatus is used as a baseline design for the impact test apparatus conducted at the Government National Laboratories (LASL, LLNL).

Supplementary Note:
It should be noted that there are varied results between the four impact apparatus. This is primarily due to the major differences in the way that the experiments are conducted and reported. In the BoM and BoE apparatus, 10-mg samples are used, and the sample is placed between parallel flat plates. The value recorded in the BoM apparatus is the minimum drop height at which a reaction occurred; whereas, in the BoE device, the results at two specified drop heights are reported. In the PA apparatus, the sample material varies as a function of density, and the amount of material required to fill the vented or unvented cup (which can vary from 8 to 20 mg). In the ERL apparatus, the striker and anvil surfaces are roughened by sand blasting. Then, the explosive is placed on the roughened surface of the anvil. Depending on the bulk density, the sample weight varies from 30 to 40 mg. Explosives that are normally received in granular form, such as PETN, RDX, and the PBX molding powders are tested as received. Cast explosives are ground, and the test sample is a 50/50 mixture of material that passes through a No. 16 USS sieve but is retained on a No. 30 USS sieve and that which passes through a No. 30 USS sieve but is retained on a No. 50 USS sieve.

The reported value in all of the impact test methods discussed is the 50% point for a given reaction occurrence. When these factors are taken into consideration, then the results are somewhat similar.

It should also be pointed out that there are almost as many different types of impact apparatus as there are test agencies, and the results from such devices may be significantly different.

Friction Sensitivity \(^{(36)}\)
The friction pendulum test determines whether or not a given material is susceptible to initiation by a specified frictional force. The Picatinny apparatus uses a 20-kilogram shoe with an interchangeable face of steel or hard fiber attached to a pendulum. The shoe is permitted to fall from a height of one meter and sweep back and forth across a grooved steel friction anvil. The results are reported as explodes, crackles, or no effect.

Steel & Fiber Shoe \(^{(36)}\) — A test consists of ten trials with the steel shoe, except when complete explosion or burning occurs in any trial. If explosion or burning occurs, the trials with the steel shoe are discontinued. Ten trials are made with the fiber-faced shoe only when complete explosion or burning occurs with the steel shoe, or as prescribed in the test directive. If the explosive passes the test with the steel shoe, no further trials are conducted. An explosive is regarded as passing the friction pendulum test if, in ten trials with the hardfiber-faced shoe, there is no more than an almost inaudible local crackling, regardless of its behavior when subjected to the action of the steel shoe.

This test is a “go-no-go” type test whereby a gross value is obtained. For this reason, the results are not usually applicable to a specific set of conditions. Although the test method and the steel and fiber shoes are standardized, this is not a mandatory test for classification.
Composition A3 (RDX/WAX — 91/09; binary)

Density
TMD — 1.672 g/cc (10)
Bulk Density —
Loaded Density — 1.63 g/cc @ 20 ksi (14)
Cast Density — 1.57 g/cc (20)

Crystal Hardness

Autoignition Temperature
Critical Temperature —

Melt Point
200°C (20)

Decomposition Temperature
250°C @ 5 sec (28)

Gas Volume
862 cc/g (28)

Detonation Pressure
300 kbars @ 1.60 g/cc (20)

Velocity Of Detonation Formulae

Velocity Of Detonation
8180 m/s @ 1.60 g/cc (20); 8470 m/s @ 1.64 g/cc (10)

Temperature of Detonation

Vacuum Stability
.60 ml-g/40 hr @ 120°C (20)
2.2 ml-g/40/160°C (9)

Hygroscopicity
0% @ 30° 90% RH (10)

Thermal Stability

Heat of Combustion
1210 cal/g

Heat of Reaction

Heat Of Formation
2.84 kcal/mole (10)

Heat Of Products Of Detonation
-1.58 (L) –1.39 (G) kcal/g (10)

Shock Sensitivity Threshold
13.4 kbars @ 1.65 g/cc (20)

LASER Initiation Threshold

TNT Equivalency
Trauzel — 143% (410 cc) (15)
Ballistic Mortar — 135% (7)
Pendulum — 130% (36)

Brisance
Sand — 51.5 g (107% TNT) (36)

Dent Test — 126% TNT (36)

Fragment — 2405 m/s @ 1.62 g/cc (20)

Impact Sensitivity

Bureau of Explosives (BoE) —
Bureau of Mines (BoM) — >100 cm (7)
Picatinny Arsenal (PA) — 41 cm (7)

Explosive Research Laboratory (ERL) —
2.5 kg/TL12 @ 81 cm (10)

Friction Sensitivity
Steel Shoe — no effect (36)
Fiber Shoe — no effect (36)

Specifications
MIL-C-440B (34)
## Composition A4 (RDX/Wax — 97/03; binary)

<table>
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<th>Value</th>
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<tbody>
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<td>Density</td>
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<td>TMD</td>
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<td>Bulk Density</td>
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<tr>
<td>Loaded Density</td>
<td></td>
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<tr>
<td>Cast Density</td>
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<td>Crystal Hardness</td>
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<td>Critical Temperature</td>
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<td>Melt Point</td>
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<td>Decomposition Temperature</td>
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<tr>
<td>Detonation Pressure</td>
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<tr>
<td>Velocity Of Detonation Formulae</td>
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<tr>
<td>Velocity Of Detonation</td>
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<tr>
<td>Temperature of Detonation</td>
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<td>Vacuum Stability</td>
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<tr>
<td>Hygroscopicity</td>
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<td>Thermal Stability</td>
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<tr>
<td>Heat of Combustion</td>
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<tr>
<td>Heat of Reaction</td>
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<tr>
<td>Heat Of Formation</td>
<td></td>
</tr>
<tr>
<td>Heat Of Products Of Detonation</td>
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<tr>
<td>Shock Sensitivity Threshold</td>
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<td>LASER Initiation Threshold</td>
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<td>TNT Equivalency</td>
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<tr>
<td>Trauzel</td>
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</tr>
<tr>
<td>Ballistic Mortar</td>
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<tr>
<td>Pendulum</td>
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<tr>
<td>Brisance</td>
<td></td>
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<tr>
<td>Sand</td>
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<tr>
<td>Dent Test</td>
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<tr>
<td>Fragment</td>
<td></td>
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<tr>
<td>Impact Sensitivity</td>
<td></td>
</tr>
<tr>
<td>Bureau of Explosives (BoE)</td>
<td></td>
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<tr>
<td>Bureau of Mines (BoM)</td>
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<tr>
<td>Picatinny Arsenal (PA)</td>
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<tr>
<td>Explosive Research Laboratory (ERL)</td>
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<tr>
<td>2.5 kg/TL12 @ 37 cm (10)</td>
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<td>Friction Sensitivity</td>
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<tr>
<td>Steel Shoe</td>
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<tr>
<td>Fiber Shoe</td>
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<tr>
<td>Specifications</td>
<td></td>
</tr>
<tr>
<td>MIL-C-440 (34)</td>
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### Composition A5  (RDX/Stearic Acid — 98.5/1.5; binary)

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<th>Property</th>
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<tbody>
<tr>
<td>Density</td>
<td>TMD — 1.757 g/cc (10)</td>
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<tr>
<td>Heat of Reaction</td>
<td>Heat Of Formation 6.1 kcal/mole (10)</td>
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<tr>
<td>Heat Of Formation</td>
<td>Heat Of Products Of Detonation -1.62 (L) –1.61 (G) kcal/g (10)</td>
</tr>
<tr>
<td>Shock Sensitivity</td>
<td>LASER Initiation</td>
</tr>
<tr>
<td>Crystal Hardness</td>
<td>Autoignition Temperature</td>
</tr>
<tr>
<td>Critical Temperature</td>
<td>TNT Equivalency</td>
</tr>
<tr>
<td>Melt Point</td>
<td>Trauzel</td>
</tr>
<tr>
<td>Decomposition Temperature</td>
<td>Ballistic Mortar</td>
</tr>
<tr>
<td>Gas Volume</td>
<td>Pendulum</td>
</tr>
<tr>
<td>Detonation Pressure</td>
<td>Brisance</td>
</tr>
<tr>
<td>Velocity Of Detonation Formulae</td>
<td>Impact Sensitivity</td>
</tr>
<tr>
<td>Velocity Of Detonation</td>
<td>Bureau of Explosives (BoE) —</td>
</tr>
<tr>
<td>Temperature of Detonation</td>
<td>Bureau of Mines (BoM) —</td>
</tr>
<tr>
<td>Vacuum Stability</td>
<td>Picatinny Arsenal (PA) —</td>
</tr>
<tr>
<td>Hygroscopicity</td>
<td>Explosive Research Laboratory (ERL) —</td>
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<tr>
<td>Thermal Stability</td>
<td>Friction Sensitivity</td>
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<tr>
<td>Heat of Combustion</td>
<td>Steel Shoe</td>
</tr>
<tr>
<td>Specifications</td>
<td>Fiber Shoe</td>
</tr>
</tbody>
</table>

### Specifications

- MIL-E-14970 (34)
Composition CH6  
(RDX/calcium stearate/graphite/polyisobutylene — 97/1.5/0.5/0.5)

Density
TMD —
Bulk Density —
Loaded Density — 1.64 g/cc @ 20 ksi (36)
Cast Density — 1.67 g/cc (36)

Crystal Hardness

Autoignition Temperature
203° C @ 1 sec, 240° C @ 10 sec (36)
Critical Temperature —

Melt Point
313° C (3)

Decomposition Temperature
184° C (36)

Gas Volume
908 cc/g (14)

Detonation Pressure
278 kbar @ 1.66 g/cc (14)

Velocity Of Detonation Formulae (28)

Velocity Of Detonation
8290 m/s @ 1.59 g/cc (14)

Temperature of Detonation

Vacuum Stability
1.0 ml/g/40 hr @ 120° C

Hygroscopicity

Thermal Stability

Heat of Combustion
2285 cal/g

Heat of Reaction
1280 cal/g

Heat Of Formation

Heat Of Products Of Detonation

Shock Sensitivity Threshold
18.0 kbar @ 1.68 g/cc (36)

LASER Initiation Threshold

TNT Equivalency

Trauzel — 150% (475 cc) (15)

Ballistic Mortar —

Pendulum —

Brisance

Sand —

Dent Test —

Fragment — 2540 m/s @ 1.72 g/cc (36)

Impact Sensitivity

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL) —

Friction Sensitivity

Specifications

MIL-C-21723 (34)
**PBX-9407** (plastic bonded explosive, RDX/FPC 461 – 94/06; binary)

**Density**
- TMD — 1.809 g/cc (10)
- Bulk Density —
- Loaded Density — 1.65 g/cc (20)
- Cast Density —

**Crystal Hardness**

**Autoignition Temperature**
- Critical Temperature —

**Melt Point**
- 204° C (36)

**Decomposition Temperature**

**Gas Volume**

**Detonation Pressure**
- 287 kbars @ 1.60 g/cc (10);
- 262 kbar @ 1.61 g/cc (10)

**Velocity Of Detonation**
- 8100 m/s @ 1.60 g/cc (20);
- 7886 m/s @ 1.61 g/cc (8)

**Temperature of Detonation**
- 2853°K @ 1.61 g/cc (10)

**Vacuum Stability**
- 0.1 – 0.3 ml/g/48 hr @ 120° C (20)

**Hygroscopicity**

**Thermal Stability**
- 0.06 cc/0.25 g/22 hr @ 120° C (20)

**Heat of Combustion**

**Heat of Reaction**

**Heat Of Formation**

**Heat Of Products Of Detonation**
- -1.60 (L) –1.46 (G) kcal/g (10)

**Shock Sensitivity**

**LASER Initiation**

**TNT Equivalency**
- Trauzel —
- Ballistic Mortar —
- Pendulum —

**Brisance**

**Impact Sensitivity**
- Bureau of Explosives (BoE) —
- Bureau of Mines (BoM) —
- Picatinny Arsenal (PA) —

**Friction Sensitivity**
- Steel Shoe —
- Fiber Shoe —

**Specifications**
- LASL 13Y-109098C (20)
- MIL-R-63419 (34)
**PBXN-5** (plastic bonded explosive Navy, HMX/Viton A — 95/05; binary)

<table>
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<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
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<td><strong>Density</strong></td>
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<tr>
<td>TMD</td>
<td>1.90 g/cc (36)</td>
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<td>Bulk Density</td>
<td>0.86 g/cc (36)</td>
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<td>Loaded Density</td>
<td>1.78 – 1.80 g/cc @ 40 ksi &amp; 60° C Vac, 1.73 g/cc @ 25 ksi (36)</td>
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<tr>
<td>Cast Density</td>
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<tr>
<td><strong>Crystal Hardness</strong></td>
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<tr>
<td><strong>Autoignition Temperature</strong></td>
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<tr>
<td>309° C @ 5 sec (36)</td>
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<tr>
<td>Critical Temperature</td>
<td>223° C (36)</td>
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<td><strong>Melt Point</strong></td>
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<tr>
<td>250° C (36)</td>
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<td><strong>Decomposition Temperature</strong></td>
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<tr>
<td><strong>Gas Volume</strong></td>
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<tr>
<td><strong>Detonation Pressure</strong></td>
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<tr>
<td>270 kbar @ 1.86 g/cc (36)</td>
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<tr>
<td><strong>Velocity Of Detonation Formulae (28)</strong></td>
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<tr>
<td><strong>Velocity Of Detonation</strong></td>
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<tr>
<td>8210 m/s @ 1.71 g/cc (36); 8820 m/s @ 1.86 g/cc (36)</td>
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<tr>
<td><strong>Temperature of Detonation</strong></td>
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<tr>
<td><strong>Vacuum Stability</strong></td>
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<tr>
<td>0.13 ml/g/48 hr @ 120° C (36)</td>
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<tr>
<td><strong>Hygroscopicity</strong></td>
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<td><strong>Thermal Stability</strong></td>
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<td><strong>Heat of Combustion</strong></td>
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<tr>
<td>Heat Of Reaction</td>
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<td>Heat Of Formation</td>
<td>-31.3 kcal/mole (36)</td>
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<td><strong>Heat Of Products Of Detonation</strong></td>
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<td>-1.56 kcal/g (L), -1.42 kcal/g (G) (36)</td>
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<td><strong>Shock Sensitivity Threshold</strong></td>
<td>18.10 @ 1.66 g/cc (36)</td>
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<td><strong>LASER Initiation Threshold</strong></td>
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<tr>
<td><strong>TNT Equivalency</strong></td>
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<tr>
<td>Trauzel</td>
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<tr>
<td><strong>Ballsitic Mortar</strong></td>
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<td>Pendulum</td>
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<td><strong>Brisance</strong></td>
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<td>Sand</td>
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<td><strong>Dent Test</strong></td>
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<tr>
<td>Fragment</td>
<td>2920 m/s @ 1.83 g/cc (36)</td>
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<td><strong>Impact Sensitivity</strong></td>
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<td>Bureau of Explosives (BoE)</td>
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<td>Bureau of Mines (BoM)</td>
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<tr>
<td>Picatinny Arsenal (PA)</td>
<td>41 cm (15)</td>
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<td><strong>Explosive Research Laboratory (ERL)</strong></td>
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<tr>
<td><strong>Friction Sensitivity</strong></td>
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<tr>
<td>Steel Shoe</td>
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<tr>
<td>Fiber Shoe</td>
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<td><strong>Specifications</strong></td>
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<td>MIL-E-81111 (34)</td>
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</table>
PBXN-6 (plastic bonded explosive Navy, RDX/Viton A — 95/05, binary)

Density

TMD —

Bulk Density — >0.650 g/cc (38)

Loaded Density —

Cast Density —

Crystal Hardness

Autoignition Temperature

Critical Temperature —

Melt Point

Decomposition Temperature

Gas Volume

Detonation Pressure

Velocity Of Detonation Formulae

Velocity Of Detonation
8440 m/s @ 1.77 g/cc (36)

Temperature of Detonation

Vacuum Stability
.12 ml/g/48 @ 100° C

Hygroscopicity

Thermal Stability

Heat of Combustion

Heat of Reaction

Heat Of Formation

Heat Of Products Of Detonation

Shock Sensitivity

LASER Initiation

TNT Equivalency

Trauzel —

Ballistic Mortar —

Pendulum —

Brisance

Sand —

Dent Test —

Fragment —

Impact Sensitivity

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL) —

Friction Sensitivity

Steel Shoe —

Fiber Shoe —

Specifications

WS-12604 (20)
DIPAM  (dipicramide, C₁₂ H₆ N₈ O₁₂)

Density

TMD — 1.79 g/cc (20)
Bulk Density —
Loaded Density —
Cast Density —

Crystal Hardness

Autoignition Temperature
504° C @ 1 sec, 305° @ 10 sec (3)
Critical Temperature —

Melt Point
304° C (20)

Decomposition Temperature
316° C (36)

Gas Volume

Detonation Pressure
269 kbar @ 1.79 g/cc (8)

Velocity Of Detonation Formulae
mm/us @ TMD = (4.35 – 0.26)/0.55 (23)

Velocity Of Detonation
7400 m/s @ 1.76 g/cc (20); 7738 m/s @ 1.79 g/cc (8)

Temperature Of Detonation
2781 °K @ 1.79 g/cc (8)

Vacuum Stability
.1 ml/g/40 @ 120° C (9)

Hygroscopicity

Thermal Stability
.1%/g/48 hr @ 210° C (9)

Heat of Combustion
-1326.8 kcal/mole (20)

Heat of Reaction

Heat Of Formation
-6.8 kcal/mole (20)

Heat Of Products Of Detonation
-1.35 (L) –1.27 (G) kcal/g (10)

Shock Sensitivity Threshold
24.17 kbar (36)

LASER Initiation Threshold
754 J/cm²/.250 us (36)

TNT Equivalency

Trauzel —
Ballistic Mortar —
Pendulum —

Brisance

Sand —

Dent Test — .119” (3)

Fragment — 2550 m/s @ 1.79 g/cc (41)

Impact Sensitivity

Bureau of Explosives (BoE) —
Bureau of Mines (BoM) —
Picatinny Arsenal (PA)— 2.5 kg @ 95 cm (3)

Explosive Research Laboratory (ERL)— 5 kg TL 12 @ 95 cm (20)

Friction Sensitivity

Steel Shoe —
Fiber Shoe —
Specifications
WS 4660 (36)
### HNS-I (hexanitrostilbene, C₁₄ H₆ N₆ O₁₂)

<table>
<thead>
<tr>
<th><strong>Density</strong></th>
<th><strong>Heat of Reaction</strong></th>
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</table>
HNS-II (hexanitrostilbene, C_{14}H_{6}N_{6}O_{12})

Density

- TMD — 1.74 g/cc (10)
- Bulk Density — 0.45 to 1.0 g/cc (10)
- Loaded Density —
- Cast Density —

Crystal Hardness

- Autoignition Temperature
  - 520° C @ 5 sec (36)
- Critical Temperature —

Melt Point

- 318° C (10)
- 325° C (35)

Decomposition Temperature

- 325° C (15)

Gas Volume

Detonation Pressure

- 200 kbar @ 1.60 g/cc (10);
- 215 kbar @ 1.65 g/cc (36)

Velocity Of Detonation Formulae

- 7000 m/s @ 1.70 g/cc (10)

Temperature of Detonation

- 3059 °K @ 1.74 g/cc (8)

Vacuum Stability

- 0.3 cc/g/hr @ 0.33 hr @ 260° C (35);
- 0.2 cc/g/hr @ 2.0 hr @ 260° C (35)

Hygroscopicity

- 0.01 cc/g/22 hr @ 0.25 g @ 120°C (10)

Thermal Stability

Heat of Combustion

- 3451 cal/g (35), -1540.3 kcal/mole (20)

Heat of Reaction

- Heat Of Formation
  - 18.7 kcal/mole (20)
- Heat Of Products Of Detonation
  - -1.42 (L) –1.36 (G) kcal/g (10)

Shock Sensitivity Threshold

- 19.0 kbar @ 1.64 g/cc (36);
- 34.0 kbar @ 1.68 g/cc (36)

LASER Initiation Threshold

- TNT Equivalency
  - Trauzel — 165% (525 cc) (15)

Ballistic Mortar —

- Pendulum — 150% (2)

Brisance

- Sand —

Dent Test —

- Fragment — 2460 m/s @ 1.61 g/cc (41)

Impact Sensitivity

- Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL) —

- 2.5 kg/TL12 @ 54 cm (10);
- 2.5 kg/TL12 @ 61 cm (35)

Friction Sensitivity

- Steel Shoe —
- Fiber Shoe —

Specifications

- WS-5003 (36)
TETRYL (2,4,6-Trinitro-phenylmethylnitramine, C$_7$H$_5$N$_5$O$_8$)

**Density**

- TMD — 1.731 g/cc (20)
- Bulk Density —
- Loaded Density — 1.67 g/cc @ 20 ksi (20);
  1.57 g/cc @ 10 ksi (7)
- Cast Density — 1.62 g/cc (20)

**Heat of Reaction**

- Heat Of Formation
  7.6 kcal/mole (20);
  4.67 kcal/mole (10)
- Heat Of Products Of Detonation
  -1.41 (L) –1.09 (G) kcal/g (10)

**Shock Sensitivity Threshold**

- 19.3 kbar @ 1.45 g/cc (36)

**Crystal Hardness**

< 1.0 Mohs (36)

**Autoignition Temperature**

- 340° C @ .1 sec (7)

**Critical Temperature**

**Melt Point**

- 129.5° C (20)

**Decomposition Temperature**

- 257° C @ 5 sec, 238° C @ 10 sec (36);
- 213°C (36)

**Gas Volume**

- 760 cc/g (7)

**Detonation Pressure**

- 226.4 kbar @ 1.614 g/cc (20); 260 kbar @ 1.71 g/cc (10); 196 kbar @ 1.53 g/cc (28)

**Velocity Of Detonation Formulae**

- mm/us = 2.742 + 2.935ρ @ 1.3 g/cc <ρ< 1.69 g/cc (10)

**Velocity Of Detonation**

- 7850 m/s @ 1.71 g/cc (10);
- 7170 m/s @ 1.53 g/cc (28)

**Temperature of Detonation**

- 2017 °K @ 1.70 g/cc (8);
- 4837 °K @ 1.6 g/cc (12)

**Vacuum Stability**

- 0.4 – 1.0 ml/g/48 hr @ 120° C (20)

**Hygroscopicity**

- 0.04% @ 30° C 90% RH (36)

**Thermal Stability**

- 5.10 cc/g/48 hr @ 120° C (10)

**Heat of Combustion**

- -836.8 kcal/mole (20)

**TNT Equivalency**

- Trauzel — 125% (356 cc) (14);
- 150% (410 cc) (15)
- Ballistic Mortar — 130% (14)

**Brisance**

- Sand — 54.2 g (113% TNT) (36)

**Impact Sensitivity**

- Bureau of Explosives (BoE) —
- Bureau of Mines (BoM) — 26 cm (14)

**Friction Sensitivity**

- Picatinny Arsenal (PA) — 2.5 kg @ 25 cm (2)

**Specifications**

- Explosive Research Laboratory (ERL)—
  - TL 12 @ 42 cm (10);
  - 5 kg/TL12 @ 28 cm (10)

- MIL-T-339 (34)
**RDX** *(Research Department Explosive, Cyclotrimethylene-trinitramine, \(\text{C}_3\text{H}_6\text{N}_6\text{O}_6\))*

**Density**

TMD — 1.806 g/cc (20)

Bulk Density —

Loaded Density — 1.68 g/cc @ 20 ksi (20); 1.60 g/cc @ 10 ksi (36)

Cast Density —

**Crystal Hardness**

2.5 Mohs (7)

**Autoignition Temperature**

316° C @ 1 sec 405° C @ .1 sec (7)

Critical Temperature — 217° C (20)

**Melt Point**

204.1° C (Type I)(20)

192° C (Type II)

**Decomposition Temperature**

260° @ 5 sec, 239° C @ 10 sec (14)

**Gas Volume**

908 cc/g (7)

**Detonation Pressure**

347 kbar @ 1.80 g/cc (8); 333.5 kbar @ 1.767 g/cc (20); 108 kbar @ 1.0 g/cc (8)

**Velocity Of Detonation Formulae**

\[
\text{mm/\text{us}} = 2.66 + 3.40p \quad (20); \\
\text{mm/\text{us}} @ \text{TMD} = (5.18 – 0.26)/0.55 \quad (23)
\]

**Velocity Of Detonation**

8639 m/s @ 1.767 g/cc (10);

8035 m/s @ 1.60 g/cc (14)

**Temperature of Detonation**

2587 °K @ 1.8 g/cc (8);

3600 °K @ 1.0 g/cc (8)

**Vacuum Stability**

0.9 cc/5 g/40 hr @ 120° C (36)

**Hygroscopicity**

0.12% @ 25° C 100% RH (36)

**Thermal Stability**

0.12 to 0.9 cc/g/48 hr @ 120° C (10)

**Heat of Combustion**

-501.8 kcal/mole (20)

**Heat of Reaction**

500 cal/g (20)

**Heat Of Formation**

14.7 kcal/mole (20)

**Heat Of Products Of Detonation**

-1.51 (L) –1.42 (G) kcal/g (10)

**Shock Sensitivity Threshold**

9.3 kbar @ 1.53 g/cc (36);

11.26 kbar @ unk g/cc (36)

**LASER Initiation Threshold**

3.1 J/cm²/.250 us @ 1.64 g/cc (Zr Dpd)(36)

**TNT Equivalency**

Trauzel — 184% (525 cc) (36)

Ballistic Mortar — 150% (7)

**Brisance**

Sand — 60.2 g (129% TNT) (36)

**Impact Sensitivity**

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) — 32 cm (7)

Picatinny Arsenal (PA) — 20 cm (28)

**Explosive Research Laboratory(ERL)**

TL 12 @ 22 cm (20);

5 kg/TL12 @ 28 cm

**Friction Sensitivity**

Steel Shoe — explodes (7)

Fiber Shoe — no effect (7)

**Specifications**

MIL-R-398C (34)
HMX (High Melting Explosive, Cyclotetramethylene-tetranitromine, \(C_4H_8N_8O_8\))

**Density**

TMD — 1.902 g/cc (20)

**Heat of Reaction**

500 cal/g (20)

**Heat Of Formation**

11.3 kcal/mole (20);
17.93 kcal/mole (10)

**Heat Of Products Of Detonation**

-1.48 (L) –1.37 (G) kcal/g (10)

**Shock Sensitivity Threshold**

**Crystal Hardness**

2.3 Mohs (7)

**LASER Initiation Threshold**

**Autoignition Temperature**

380° C @ 0.1 sec, 306° C @ 1.0 sec (15,36)

**TNT Equivalency**

Critical Temperature — 253° C (20)

Trauzel — 145% (413 cc) (36)

**Detonation Pressure**

389.8 kbar @ 1.90 g/cc (20)

Bureau of Explosives (BoE) —

**Decomposition Temperature**

200° C (36)

Bureau of Mines (BoM) — 60 cm (14)

**Ballistic Mortar** — 150% (36)

**Decomposition Temperature**

200° C (36)

2364 °K @ 1.90 g/cc (8)

**Impact Sensitivity**

Picatinny Arsenal (PA) — 23 cm (14)

**Detonation Temperature**

2364 °K @ 1.90 g/cc (8)

Explosive Research Laboratory(ERL) —

**Dent Test** —

Fragment — 2970 m/s @ 1.89 g/cc (10, 40)

**Thermal Stability**

0.07 cc/g/48 hr @ 120° C (36)

**Impact Sensitivity**

Steel Shoe — explodes

**Fiber Shoe** — no effect

**Specifications**

MIL-H-45444 (20)

**Heat of Combustion**

-660.7 kcal/mole (20)

**Friction Sensitivity**

Steel Shoe — explodes

**Fiber Shoe** — no effect

**Specifications**

MIL-H-45444 (20)
DATB (1,3-Diamino-2,4,6-trinitrobenzene, C₆H₅N₅O₆, nitroaromatic)

Density (Form I)

TMD — 1.838 g/cc (20)

Bulk Density —

Loaded Density —

Cast Density —

Crystal Hardness

Autoignition Temperature
384° C @ 1 sec

Critical Temperature — 322° C (20)

Melt Point
286° C (20)

Decomposition Temperature

Gas Volume

Detonation Pressure
247.7 kbar @ 1.780 g/cc (20);
259 kbar @ 1.78 g/cc (8)

Velocity Of Detonation Formulae
mm/us = 2.480 + 2.852p (20)

Velocity Of Detonation
7600 m/s @ 1.780 g/cc (20)

Temperature of Detonation
2477 °K @ 1.79 g/cc (8)

Vacuum Stability
0.1 – 0.3 ml/g/48 hr @ 120° C (20)

Hygroscopicity

Thermal Stability
<0.03 cc/g/48 @ 120° C (20)

Heat of Combustion
-711.5 kcal/mole (20)

Heat of Reaction
300 cal/g (20)

Heat Of Formation
-23.6 kcal/mole (20)

Heat Of Products Of Detonation
-1.26 (L) – 1.15 (G) kcal/g (10)

Shock Sensitivity Threshold

LASER Initiation Threshold

TNT Equivalency

Trauzel — 196% (560 cc) (2, 15)

Ballistic Mortar —

Pendulum — 150% (36)

Brisance

Sand — 50.4 g (105% TNT) (36)

Dent Test —

Fragment — 3450 m/s @ 1.89 g/cc (36)

Impact Sensitivity

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL)—

Vacuum Stability
0.1 – 0.3 ml/g/48 hr @ 120° C (20)

Friction Sensitivity

Steel Shoe —

Fiber Shoe —

Specifications
TATB (1,3,5-triamino – 2,4,6-trinitrobenzene; C₆H₆N₆O₆; nitroaromatic)

Density

TMD — 1.937 g/cc (20)

Bulk Density —

Loaded Density — 1.86 g/cc @ 20 ksi @ 120°C (20)

Cast Density —

Crystal Hardness

Autoignition Temperature
384°C @ 1 sec (8)

Critical Temperature — 347°C (20)

Melt Point
480°C (20), 452°C (10)

Decomposition Temperature

Gas Volume

Detonation Pressure
326 kbar @ 1.895 g/cc 331°C (8); 255.6 kbar @ 1.847 g/cc (20); 172 kbar @ 1.5 g/cc (20)

Velocity Of Detonation Formulae

\[ m/s = 2480 + 2852\rho \] (20)

\[ \text{mm/us} @ \text{TMD} = (4.59 – 0.26)/0.55 \] (23)

Velocity Of Detonation
7666 m/s @ 1.847 (20); 8411 m/s @ 1.895 g/cc (8)

Temperature of Detonation
1887 °K @ 1.895 g/cc (8)

Vacuum Stability

Hygroscopicity

Thermal Stability

Heat of Combustion
-735.9 kcal/mole (20)

Heat of Reaction
600 cal/g (20)

Heat Of Formation
-33.4 kcal/mole (20)

Heat Of Products Of Detonation
-1.20 (L) –1.08 (G) kcal/g (10)

Shock Sensitivity Threshold

LASER Initiation Threshold

TNT Equivalency

Trauzel — 132% (375 cc) (2,15)

Ballistic Mortar —

Pendulum — 128% (2)

Brisance

Sand —

Dent Test —

Fragment — 2399 m/s @ 1.854 g/cc (10,40)

Impact Sensitivity

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL) —

TL 12 @ >320 cm (20); 5 kg/TL12 @ 1770 cm (10)

Friction Sensitivity

Steel Shoe —

Fiber Shoe —

Specifications

LASL 13Y-188025 (20)
PETN  (pentaerythritol-tetranitrate, C₅H₈N₄O₁₂, aliphatic-nitrate-ester)

**Density**
- TMD (20) — 1.778 g/cc (20)
- Bulk Density —
- Loaded Density — 1.71 @ 20 ksi (20), 1.638 @ 20 ksi (10); 1.57 g/cc @ 10 ksi (36)
- Cast Density —

**Crystal Hardness**
- 2.0 Mohs (7)

**Autoignition Temperature**
- 272° C @.1 sec 244 °C @ 1 sec (14)

**Critical Temperature** — 192° C (20); 200° C (8)

**Melt Point**
- 142.9°C (20)

**Decomposition Temperature**
- 225 C @ 5 sec, 210° C @ 10 sec (36)

**Gas Volume**
- 790cc/g, 823cc/g (2,6,23)

**Detonation Pressure**
- 335 kbar @ 1.77 g/cc (10); 306 kbar @ 1.67 g/cc (20), 87 kbar @ 0.99 g/cc (10)

**Velocity Of Detonation Formulae**
\[
\text{mm/us} = 1.608 + 3.933p @ 0.57 \text{ g/cc} < p < 1.585 \text{ g/cc (20, 15, 23)}
\]

**Velocity Of Detonation**
- 7975 m/s @ 1.67 g/cc (20);
- 8260 m/s @ 1.76 g/cc ((20)

**Temperature of Detonation**
- 2833 °K @ 1.77 g/cc, 3970 °K @ 1.0 g/cc;
- 4493 °K @ 0.50 g/cc, 4442 °K 0.25 g/cc (10)

**Vacuum Stability**
- 2.0 to 11.0 cc/g/40 hr @ 120° C (36)

**Hygroscopicity**
- 0% @ 30° C 90% RH (10)

**Thermal Stability**
- 0.10 to 0.14 cc/g/22 hr @ 0.25 g @ 120° C (10)

**Heat of Combustion**
- 618.7 kcal/mole (20)

**Heat of Reaction**
- 300 cal/g @ 1.74 (20)

**Heat Of Formation**
- -110.34 kcal/mole (20)
- -128.7 kcal/mole (10)

**Heat Of Products Of Detonation**
- -1.49 (L) –1.37 (G) kcal/g (10)

**Shock Sensitivity Threshold**
- 26.0 kbar @ unk g/cc (36)

**LASER Initiation Threshold**

**TNT Equivalency**
- Trauzel — 173% (493 cc) (36)
- Ballistic Mortar — 145% (14)
- Pendulum —

**Brisance**
- Sand — 62.7 g (131% TNT) (14)

**Impact Sensitivity**
- Bureau of Explosives (BoE) —
- Bureau of Mines (BoM) — 17 cm (14)
- Picatinny Arsenal (PA) — 15 cm (14)

**Explosive Research Laboratory (ERL)**
- TL 12 @ 12 cm (20);
- 5 kg/TL12 @ 11 cm (10)

**Friction Sensitivity**
- Steel Shoe — crackles
- Fiber Shoe — no effect

**Specifications**
- MIL-P-387 (34)
**CYCLOTOL** (TYPE I — RDX/TNT, 75/25, binary)

**Density**
- TMD — 1.765 g/cc (20)
- Bulk Density —
- Loaded Density —
- Cast Density — 1.74/1.75 g/cc-vac melt (20); 1.71 g/cc typ. (14)

**Crystal Hardness**

**Autoignition Temperature**
- Critical Temperature — 208° C (20)

**Melt Point**
- 79° C (cast) (20)

**Decomposition Temperature**
- 280° C @ 5 sec (14)

**Gas Volume**
- 862 cc/g (23)

**Detonation Pressure**
- 316 kbar @ 1.752 g/cc (10);
- 281 kbar @ 1.73 g/cc (36)

**Velocity Of Detonation Formulae**
- mm/us® = 8.210 [(1 – 4.89 (10^-2)/R) – 0.119/R (R – 2.44)] (20)
- mm/us @ TMD = (4.71 – 0.26)/0.55 (23)

**Detonation Temperature**
- Bureau of Mines (BoM) —
  - 2829 °K @ 1.44 g/cc (8)

**Vacuum Stability**
- .41 ml/g/48 hr @ 100° C (36)

**Hygroscopicity**

**Thermal Stability**
- 0.25 to 0.94 cc/g/48 hr @ 120° C (10)

**Impact Sensitivity**
- Bureau of Explosives (BoE) —
- Bureau of Mines (BoM) — 51 cm (14)

**Picatinny Arsenal (PA) —**

**Explosive Research Laboratory (ERL) —**
- TL 12 @ 36 cm (20);
  - 5 kg/TL12 @ 33 cm (10)

**Friction Sensitivity**
- Steel Shoe — no effect (14)
- Fiber Shoe — no effect (14)

**Specifications**
- MIL-C-13477 (34)

**Heat of Reaction**

**Heat Of Formation**

**Heat Of Products Of Detonation**
- -1.57 kcal/g (10)

**Shock Sensitivity Threshold**

**LASER Initiation Threshold**

**TNT Equivalency**
- Trauzel — 100% (285 cc) (15)

**Ballsitic Mortar —**

**Pendulum —**

**Brisance**
- Sand — 54 g (113% TNT) (14)

**Dent Test —**
- Fragment — 2790 m/s @ 1.754 g/cc (10,40)

**Impact Sensitivity**

**Explosive Research Laboratory (ERL) —**
- TL 12 @ 36 cm (20);
  - 5 kg/TL12 @ 33 cm (10)

**Friction Sensitivity**
- Steel Shoe — no effect (14)
- Fiber Shoe — no effect (14)

**Specifications**
- MIL-C-13477 (34)
TNT (2,4,6-trinitrotoluene, C₇H₅N₃O₆, nitroaromatic)

Density
TMD — 1.653 g/cc (20), 1.465 g/cc (L) (36)
Bulk Density — 0.97 g/cc (36)
Loaded Density — 1.55 g/cc @ 20 ksi (20)
Cast Density — 1.61 – 1.62 g/cc @ vac (20)

Crystal Hardness
1.4 Mohs (7)

Autoignition Temperature
570° @ .1 sec, 520 °C @ 1 sec (36)
Critical Temperature — 288°C (20)

Melt Point
80 – 82°C (20)

Decomposition Temperature
475° C @ 5 sec, 465° C @ 10 sec (14);
281° C (36)

Gas Volume
730 cc/g (36)

Detonation Pressure
170 kbar @ 1.56 g/cc (36); 186.6 kbar @ 1.637 g/cc (20); 200 kbar @ 1.63 g/cc (10)

Velocity Of Detonation Formulae
\[
\text{mm/us} = 1.873 + 3.187 \rho \\
\text{at} \ 0.9 < \rho < 1.534 \text{g/cc (20)}
\]

Velocity Of Detonation
6942 m/s @ 1.637 g/cc (vac cast) (20);
6800 m/s @ 1.56 g/cc (pressed) (36)

Temperature of Detonation
2829 °K @ 1.64 g/cc (8)

Vacuum Stability
0.2 ml/g/48 hr @ 120°C (20)

Hygroscopicity
0.03% @ 30°C 90% RH (36)

Thermal Stability
≈0.005 cc/g/48 hr @ 120°C (10)

Heat of Combustion
-817.2 kcal/mole (20)

Heat of Reaction
300 cal/g @ 1.57 g/cc (20)

Heat Of Formation
-12.0 kcal/mole (20)

Heat Of Products Of Detonation
-1.09 (L) –1.02 (G) kcal/g (10)

Shock Sensitivity Threshold

LASER Initiation Threshold

TNT Equivalency
Trauzel — 100% = 285 cc (36)
Ballistic Mortar — 100% = (36)

Brisance
Sand — 48 g = 100% TNT (36)

Dent Test —

Impact Sensitivity
Bureau of Explosives (BoE) —
Bureau of Mines (BoM) — 100 cm (14)
Picatinny Arsenal (PA) — 36 cm (14)

Explosive Research Laboratory (ERL) —
Tl 12 @ 154 cm (20);
5 kg/TL12 @ 80 cm (10)

Friction Sensitivity
Steel Shoe — crackles (14)
Fiber Shoe — no effect (14)

Specifications
MIL-T-248C (34)
MIL-T-1150 (36)
Composition B3 (RDX/TNT, 60/40, binary)

Density
TMD — 1.75 g/cc (20)
Bulk Density —
Loaded Density —
Cast Density — 1.730 g/cc @ vac (20)

Crystal Hardness

Autoignition Temperature
526° C @ .1 sec (36)
Critical Temperature — 214°C (20)

Melt Point
79°C (TNT melt) (20)

Decomposition Temperature
255° C (23)

Gas Volume

Detonation Pressure
243 kbar @ 1.68 g/cc (36);
287 kbar @ 1.72 g/cc (23)

Velocity Of Detonation Formulae
\[ \text{mm/us} = 7.859 \left( 1 - 2.84 \left( 10^{-2}$/R \right) \right) \left( R - 1.94 \right) \] (20);
\[ \text{mm/us @ TMD} = (4.71 - 0.26)/0.55 \] (23)

Temperature of Detonation

Vacuum Stability
0.2 – 0.6 ml/g/48 hr @ 120°C (20)

Hygroscopicity
.05% @ 90% RH @ 30° C

Thermal Stability

Heat of Combustion

Heat of Reaction

Heat Of Formation

Heat Of Products Of Detonation

Shock Sensitivity Threshold
33.3 kbar @ 1.72 g/cc (36)

LASER Initiation Threshold

TNT Equivalency

Trauzel —
Ballistic Mortar —
Pendulum —

Brisance

Sand —

Dent Test —

Fragment — 2368 m/s @ 1.73 g/cc (36)

Impact Sensitivity

Bureau of Explosives (BoE) —
Bureau of Mines (BoM) —
Picatinny Arsenal (PA) —

Explosive Research Laboratory (ERL) —

TL 12 @ 59 cm (20):
2.5 kg/TL12 @ 40 to 80 cm (10)

Friction Sensitivity

Steel Shoe —
Fiber Shoe —

Specifications

MIL-C-401C (34)
MIL-C-45113 (34)
**XTX-8003 (EXTEX, PETN/SYLGARD-182 80/20)**

**Density**
- TMD — 1.556 g/cc (20)
- Bulk Density —
- Loaded Density —
- Cast Density — 1.50 g/cc (20)

**Crystal Hardness**

**Autoignition Temperature**
- Critical Temperature —

**Melt Point**
- 129 to 135 °C (20)

**Decomposition Temperature**

**Gas Volume**

**Detonation Pressure**
- 170 kbar @ 1.546 g/cc (10)

\[
\text{mm/us}^\circ = 7.260[(1 - 0.191 \times 10^{-2}/R) - 2.12 \times 10^{-4}/R] (R - 0.111) \quad (20)
\]

**Velocity Of Detonation**
- 7248 m/s @ 1.53 g/cc (20)

**Temperature of Detonation**

**Vacuum Stability**
- 0.2 ml/g/48 hr @ 100°C (20);
- 0.11 ml/g/40 hr @ 120°C (15)

**Hygroscopicity**

**Thermal Stability**
- <0.02 cc/22 hr @ 0.25 g @ 120°C (10)

**Heat of Combustion**

**Heat of Reaction**
- 300 cal/g (PETN) (20)

**Heat Of Formation**
- -39 kcal/mole (10)

**Heat Of Products Of Detonation**
- -1.16 (L) –1.05 (G) kcal/g (10)

**Shock Sensitivity Threshold**

**LASER Initiation Threshold**

**TNT Equivalency**
- Trauzel — 102%

**Ballistic Mortar —**

**Pendulum —**

**Brisance**

**Gas Volume**

**Detonation Pressure**
- 170 kbar @ 1.546 g/cc (10)

**Impact Sensitivity**
- Bureau of Explosives (BoE) —
- Bureau of Mines (BoM) —
- Picatinny Arsenal (PA) —

**Explosive Research Laboratory (ERL) —**
- TL 12 @ 30 cm (20);
- 5 kg/TL12 @ 21 cm (10)

**Friction Sensitivity**
- Steel Shoe —
- Fiber Shoe —

**Specifications**
- LASL-13Y-104481F (20)
OCTOL  (HMX/TNT  75/25, binary)

Density
TMD — 1.835 g/cc (20)
Bulk Density —
Loaded Density —
Cast Density — 1.825 g/cc @ vac (20)
1.81 g/cc typ. (7)
Crystal Hardness

Autoignition Temperature
Critical Temperature — 281°C (20)

Melt Point
79°C (TNT melt) (20)

Decomposition Temperature
350°C @ 5 sec (7)

Gas Volume
830 cc/g (7)

Detonation Pressure
333.5 kbar @ 1.809 g/cc (20);
342 kbar @ 1.821 g/cc (10)

Velocity Of Detonation Formulae
\[ \text{mm/us} = 8.84[(1 - 6.9 \times 10^{-2}/R)
- (9.25 \times 10^{-2}/R) (R - 1.34)] \]

Velocity Of Detonation
8452 m/s @ 1.809 g/cc (20);
8540 m/s @ TMD (36)

Temperature of Detonation

Vacuum Stability
0.1 – 0.4 ml/g/48 hr @ 120°C (20);
2.66 ml/5 g/40 hr @ 140°C (11)

Hygroscopicity

Thermal Stability
0.18 cc/g/48 hr @ 120°C (10)

Heat of Combustion
2.67 kcal/g (11)

Heat of Reaction

Heat Of Formation
2.57 kcal/mole (11)

Heat Of Products Of Detonation
-1.57 (L) –1.43 (G) kcal/g (10)

Shock Sensitivity Threshold
14.7 kbar @ 1.68 g/cc (36)

LASER Initiation Threshold

TNT Equivalency

Trauzel —
Ballistic Mortar — 116% (7)

Pendulum —

Brisance

Sand — 62.1 g (129% TNT) (7)

Dent Test —

Fragment — 1877 m/s @ 1.81 g/cc (11)
2551 m/s @ 1.82 g/cc (36)

Impact Sensitivity

Bureau of Explosives (BoE) —

Bureau of Mines (BoM) —

Picatinny Arsenal (PA) — 43 cm (25 mg) (7)

Explosive Research Laboratory (ERL) —

TL 12 @ 38 cm (20);
5 kg/TL12 @ 41 cm (10)

Friction Sensitivity

Steel Shoe — no effect (11)
Fiber Shoe — no effect (11)

Specifications

MIL-O-45445A (34)
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