TECHNICAL BACKGROUND AND TERMINOLOGY

To comprehend the technical activities of Picatinny Arsenal, some basic understanding of explosives, the components of an explosive train, and the various types of projectiles is necessary. It is also necessary to understand the role of safety in the manufacture and handling of explosives. The following section is designed to provide a brief introduction to the subject. The bibliography at the end of this report also contains numerous references devoted to explosives, their history, production and use.

Explosives

An explosive is defined as a substance, which because of a blow, friction, or the application of heat, rapidly decomposes to a more stable form, usually a gas. This decomposition and increase in pressure is accompanied by the production of considerable amounts of heat. Explosives used by the military are classified as "low" or "high" explosives.

Low explosives are those substances whose rate of decomposition is slow enough to make them safe as a propelling charge in a gun. These are referred to as deflagration or burning explosives. The "action" associated with low explosives can be described as follows:

> "The explosion progresses from the initial point by the heating of successive layers of the explosive to the explosion temperature. These explosives therefore, burn on the outside or exposed surface only. In these explosives the rapidity of the reaction is not great under ordinary conditions, but increases greatly if the explosion takes place under high pressure. . . Different low explosives differ considerably in their rapidity of reaction or, as usually expressed, their rate of burning.[1]

Black powder is an explosive that can serve as both a low and high explosive, depending on how it is used and contained. Until the late nineteenth century it was the sole explosive in military use and it found services as both a propelling charge and the projectile charge. With the development of new high explosives in the 1880's it was used primarily as a propellant. Today, black powder is primarily used as a delay element in a fuze and the exploding charge in a grenade. Black powder is hydroscopic (i.e., it reacts with or absorbs water), unstable, has a burn rate difficult to control, is dangerous to handle, leaves a residue in a gun barrel that corrodes metal and produces excess flash and smoke.

Nitrocellulose is another common low explosive. It is a product of the nitration of cotton, is generally referred to as smokeless powder, though it is neither smokeless nor a powder. Developed in 1838 by Pelouze, the early use of gun cotton, as it was first called, was marked by disaster. In its raw form, gun cotton is entirely too sensitive and unfit for general use. In 1886, Paul Vieille used ether and alcohol to colloid the gun cotton, and his Poudre "B" was quickly adopted by the French Military. Alfred Nobel mixed nitrocellulose and nitroglycerine to form the first double-based powder, Ballistite and, in 1889, the British took as their standard military propellant powder an adaption of the Nobel powder which they called "cordite," composed of 58% nitroglycerine, 37% nitrocellulose, 5% petroleum jelly.

Shortly thereafter the US Navy built a smokeless powder plant in Newport, RI where Lt. Bernardou developed a straight colloided nitrocellulose containing 12.45% nitrogen. The Army closely followed the Navy experiments and in 1907 built their own nitrocellulose plant at Picatinny Arsenal.

World War I exposed the weaknesses of nitrocellulose as a propellant. In too dry a climate, the solvents vaporized and thus increased its rate of burn. In a wet climate, it absorbed moisture and the rate of burn decreased. World War I was the first conflict in which night firing of large guns was a common occurrence. Nitrocellulose was not desirable for such purposes because it produced a brilliant flash which revealed the location of gun emplacements. As a response to this deficiency, in 1917-1918 Picatinny Arsenal developed P.A. Compound #2, (oxnilid and glue), which was shredded and mixed with the powder grains or bagged on top of the propellant charge. It served to cool the gases below the flash point when they were ejected into the atmosphere. P.A. Compound #2 worked, but there was still a demand for a powder that was both non-hydroscopic and flashless without any additives. In 1929, DuPont developed FNH Powder M1 that was flashless in some guns and non-hydroscopic in all. Picatinny researchers developed P.A. Flashless Non-Hydroscopic Powder, M3 in 1936 using pyrocotton with a nitrogen content of 12.6%, diphenylamine (DPA), a stabilizer which inhibits deterioration of powder, dinitrotululene solid which reduces hydroscopicity of the powder, and dibutylphthalate (DBT), an inert cooling agent added to form FNH. The ratio of the chemicals depended on the gun for which the powder was intended.

When an explosive decomposes at such a rate as to be considered instantaneous, it is considered a "high explosive". The "action" associated with high explosives can be described as follows:

> ". . . the explosion travels from the initial point in a wave of vibration known as the explosive wave. The successive layers of [of the explosive] are not raised to the temperature of explosion by the heat derived from the preceding ones, but the energy required to break up the successive layers is furnished first by the initial impulse produced by a primer or other means, and then by the explosive wave. The explosive wave consists of molecules of the products of combustion of the part of the explosive last exploded. The impact of these rapidly moving molecules on the adjacent parts of the explosive causes it to explode and furnish in turn new rapidly moving molecules of the explosive wave. The speed of the explosive wave, or rate of detonation, varies considerably in different high explosives."[2]

This highly disruptive effect on the surrounding medium is called a denotation. The characteristics of high explosives make them unsuitable as propellants but ideal as bursting charges.

High explosives are categorized according to their energy, rate of detonation, sensitivity to friction or a blow, and brisance. Brisance "refers to that quality or property of a high explosive evidenced by its capacity upon detonation, to shatter any medium confining it."[3] Primary explosives (single compound) are differentiated from derived explosives (usually TNT mixed with other primary explosives). High explosives used or produced at Picatinny Arsenal included:

1) TNT – Trinitrotoluene. Known as early as 1863, it was first used as an explosive in 1904. TNT is safe under normal handling conditions. It will not form unstable compounds with metals, does not absorb water, and is a powerful, brisant explosive. However, TNT does pose a health threat unrelated to its explosive capability. Vapors released during the production of TNT are poisonous as is TNT dust.

2) Tetryl – Trinitropheylmethylnitramine. A derivative of Benzene, Tetryl is almost insoluble in water and is more sensitive to shock or friction than TNA (see below). It is readily exploded by the penetration of a rifle bullet. Though not a good bursting charge, it is an excellent booster, or initiator of the bursting charge. Tetryl is poisonous if ingested.

3) Trytol – 65% Tetryl and 35% TNT – Trytol has about the same sensitivity and brisance as Tetryl but, unlike Tetryl, it can be cast. Trytol is used as a bursting charge.

4) TNA – Tetranitroaniline. Derived from benzene, TNA was first patented in 1912. It does not absorb moisture, will not react with metals, and creates poisons as it is produced. TNA is sensitive to shock or friction and will explode violently when hit with rifle fire. TNA is expensive to manufacture.

5) Amatol – Ammonium Nitrate and TNT either 50/50 or 80/20. The compound is hydroscopic, relatively insensitive to blows or friction, and will detonate from a severe impact or blow. Amatol will not form compounds with meals other than copper and tin. More insensitive than TNT it has the same rate of detonation and the same explosive strength. It is formed by melting TNT in a steam jacketed mixer, adding ammonium nitrate, and then stirring until each grain of ammonium nitrate is coated with TNT. 50/50 Amatol is very fluid and can be poured or case in shells. 80/20 Amatol is plastic, like moist brown sugar, and is filled by tamping or screwing.

6) Cyclonite (cyclotrimethylenetrinitramine) – the RDX's – (Research Department Explosives). In its pure form cyclonite is highly sensitive and brisant, and cannot be cast. RDX Compound A is 91% cyclonite and 9% wax. It is a good explosive for armor piercing shells. RDX Compound B is 60% cyclonite, 39% TNT and 1% wax. It is especially good for fragmentation bombs. RDX Compound C is 88% cyclonite and 12% plasticizer. More brisant and just as insensitive as TNT, Compound C can be formed on the spot, shaped or tamped into place, making it an ideal demolition explosive.

7) Haleite (ethylene dinitramine) – EDNA. Names for Dr. Hale, former head research scientist at Picatinny Arsenal, for many years Haleite had the highest brisance of explosives of comparable sensitivity and a higher rate of detonation than TNT. EDNA cannot be cast.

8) Mercury Fulminate. Derived from the interaction of alcohol on mercury nitrate in nitric acid solution, mercury fulminate is only produced in small amounts. Mercury fulminate detonates completely and with violence from a spark or hot wire. It is a most suitable detonator material since it will not absorb moisture. When dry it will not react with metals; when wet, it will react with brass.

9) Lead Azide – PbN6). A white crystalline powder, lead azide has largely replaced mercury fulminate as a detonator material. Nonhydroscopic, it has good stability once pressed into a detonator cup. Before pressing, it is so dangerous that it must be stored in water and handled only in very small amounts.

10) Explosive D – Ammonium Picrate. Explosive D was patented by Alfred Nobel in 1888. It is very insensitive to shock and friction and well suited as a bursting charge in armor piercing projectiles. Explosive D is manufactured by the neutralization of picric acid with ammonia. There are no serious dangers in its manufacture and it can be loaded with hydraulic pressure or hand stemming.

11) Picric Acid – Trinitrophenol. Picric Acid was developed in France as an explosive in 1886. It is derived from benzene, an inflammable liquid byproduct of the manufacture of coke. It readily forms sensitive explosive salts when in contact with metals. A weak poison, picric acid is also known as a dye.

12) Nitrostarch Explosives. Adopted during World War I to compensate for the shortage of TNT, Nitrostarch is formed by the treatment of starch with a mixture of nitric and sulphuric acids. Cassava and tapioca starches provide the best service. More sensitive to impact than TNT, it was fairly cheap to produce. Trojan grenade explosive and trojan trench mortar shell explosive were composed of 40% nitrostarch and varying amounts of ammonium nitrate and sodium nitrate. Grenite contained 95% nitrostarch.

IMPORTANT HIGH EXPLOSIVES ARRANGED BY SENSITIVITY AND BRISANCE

Decreasing Sensitivity		Increasing Brisance	
Mercury fulminate	5	Lead azide	18
Lead Azide	10	Mercury fulminate	22
PETN	17	Explosive D	
EC blank fire	19	Amatol 50/50	39
Tetryl	26	TNT	43
Tetrytol	28	EC blank fire	45
Cyclonite	32	Tritonal	46
Pentolite	34	Ednatol	48
Torpex	38	Haleite	51
Haleite	48	RDX-B	52
RDX-B	75	Trytol	52
Amatol 50/50	95	Tetryl	53
Ednatol	95	Pentolite	53
TNT	95-100	Torpex	58
Explosive D	100+	Cyclonite	59
Tritonal	100+	PETN	62

The Explosive Train

"The explosive train" is the term used to describe the process of detonation in military ammunition. The sequence of action and number of actions may vary but in both propellant explosive train and the projectile or bomb explosive train the basic actions remain the same.

The initiator of all action is the primer, usually black powder, which is ignited by a spark, friction, or electricity. The primer in turn fires the detonator, which consists of small amounts of extremely powerful explosives (usually either lead azide or mercury fulminate). The detonator fires the booster, a larger amount of less volatile explosive. The booster, usually tetryl, is powerful enough to detonate the bursting charge, but in itself does not make a good burster. The bursting charge can be one of any of a number of explosives, depending on the purpose of the munition. This purpose may be armor-piercing, concrete-piercing, anti-tank, anti-personnel, pyrotechnic or chemical.

There are four basic stages in the explosive train of large scale military ammunitions. In general, the explosive train starts with the ignition of a relatively small amount of highly sensitive explosive in the primer. The blast of the primer then ignites the detonator which, in turn, ignites the booster which then sets off the bursting charge. Because of this "chain reaction," it is possible to ignite a large amount of relatively stable high explosive (the bursting charge) in a relatively short period of time. If there is a need to delay or time the action of the fuze, relay or delay pellets of black powder can be added to control the timing of the denotation. With this system, it is also possible to keep the fuzes and bursting charges separate from one another until the bomb is actually to be used, thus allowing the bursting charges to be handled without fear of premature explosion.

GLOSSARY OF ORDNANCE TERMINOLOGY

(Note: This glossary emphasizes historically relevant terminology. It is not intended as a comprehensive listing of modern ordnance terminology.)

Aircraft Ammunition: Anything dropped out of a plane, including bombs and certain pyrotechnics. Bombs, pyrotechnic ammunition, and rocket ammunition are classified in the same fashion as artillery ammunition.

Ammunition: Any material used in attack or defense in warfare intended to inflict damage upon the enemy; artillery, aircraft, rocket, small arms, etc.

Artillery Ammunition: Classified three different ways. 1. According to service use: Service Ammunition (used to inflict damage upon the enemy); Practice Ammunition (used to train troops); and Blank Ammunition. 2. According to tactical use: High Explosive, Armor Piercing, Chemical, Smoke. 3. According to the method of containing the propellant: Fixed, Semi-Fixed, or Separate Loaded.

Artillery Primer: A device for igniting the propellant powder that imparts motion to the projectile, located in the end of the cartridge case with the powder.

Brisance: That quality or property of a high explosive evidenced by its capacity, upon detonation, to shatter any medium confining it.

Caliber: Diameter of the bore of a gun, measured either metrically or in inches. It also describes the size of ammunition.

Cannon: A weapon too heavy to be carried by hand including guns, howitzers and mortars, except for trench mortars.

Cartridge: A complete round of small arms ammunition, or the casing that contains propellant powder for fixed or semi-fixed ammunition.

Complete Round: All components required to fire a gun once; the ultimate objective in artillery ammunition design and manufacture; not necessarily physically attached as a unit. Artillery ammunition is classified according to service use (service ammunition, target or practice, drill, blank-saluting); tactical use (high explosive, armor-piercing, chemical, smoke, illuminating, canister, or special).

Deflagration: Slower reactions of low explosives, or burning.

Detonation: Comparatively fast rate of reaction of a high explosive.

Detonator: A stage in the explosive train, used to set off an explosion.
Explosive: Substance that rapidly changes from its initial state, usually but not necessarily a solid, to a gaseous state by application of heat, friction, a blow, etc.

Explosive Train: the steps taken in military ordnance to control the explosion of a shell, bomb, etc. the steps include the primer, detonator, booster, and bursting charge.

Fixed: One type of a complete round of ammunition, where the propellant powder is contained in a cartridge case permanently attached to the projectile.

Fuze: A mechanism or device for controlling the ignition or detonation of a projectile.

Fuze Primer: A small explosive component for initiating a detonation in an explosive train and transmitting it to the next component.

Grenades: Explosive or chemical-filled projectiles of a size and shape convenient for throwing by hand or projecting from a rifle or a launcher. Grenades are designated defensive, offensive, or chemical.

Guns Long-range, high-velocity, high-pressure weapons fired at low elevations. They are the heaviest type of cannon.

High Explosives: Initiated usually by shock or blow, high explosives have a very high rate of reflection and disruptive effect.

Howitzer: Shorter, lighter-weight weapon fired at higher elevations than guns, resulting in shorter range, and at targets which cannot be reached by direct fire.

Land Mines: Containers, metal, plastic, or wood, filled with high explosives or chemical agents. They are designed for placing in or on the ground for denotation by enemy vehicles or personnel. They can also be detonated by remote control.

Loading: The filling of shells, bombs, etc., by means of casting, pressing, or pelleting.

Low Explosives: Initiated by flame or spark, lower rate of reaction and less disruptive effect than high explosives.

Mortars: Weapons even shorter, lighter and more mobile than howitzers. The muzzle velocity and chamber pressure are less and the angle of fire is greater, particularly for trench mortars which are of the smooth-bore variety. Some of the larger mortars are rifled. Mortars are used against troops in trenches or foxholes, machine gun nests, and obstructions and barriers, and they are adapted to plunging fire at high angles even up to 85 degrees. They are excellent for firing over local obstructions and hills, preparatory to infantry advance. They provide indirect fire, usually with a high trajectory.

Munition: Armament or ammunition.

Ordnance: Everything the Army fights with including tanks, artillery and ammunition, self-propelled mounts, carriages and recoil mechanisms, fire control apparatus and instruments, combat and transport vehicles, small arms and ammunition, rocket launchers and rockets, bombs, pyrotechnics, grenades, and mines.

Percussion Primer: Fired by a firing pin, the flash being transmitted to the powder charge.

Primer: Element of the explosive train. It ignites the powder charge.

Rifle: A weapon using rifling in its barrel to impart a stabilizing twist to a projectile.

Rocket: A container in which gases are generated at high pressure with a vent or nozzle through which gases escape in the form of a jet.

Rocket Launchers: Guide rails or guide tubes fitted with an electric ignition device.

Semifixed: A form of the complete round of ammunition. The propellant powder is contained in bags in a cartridge case not permanently attached to a projectile, but removable in the field so that the charge may be adjusted.

Separate Loaded: The third form of the complete round of ammunition. Propellant powder is contained in bags which are loaded separately into the breech of the gun behind the projectile.

Small Arms: Weapons .60 inches or under in caliber used primarily by the infantry; rifles, semi-automatic rifles; automatic rifles, pistols, carbines, machine guns, submachine guns.

Small Arms Ammunition: Bullets; categorized as ball, armor-piercing, tracer, incendiary, or guard. Small arms ammunition also includes blanks, rifle-grenades, subcaliber ammunition and shotgun shells.

Small Arms Complete Round or Cartridge: Contains a bullet to perform the mission at the target, a cartridge case to contain the primer and propellant powder, and a primer to ignite the propellant powder when the firing pin strikes it.

Tracers: A bright burning composition placed at the base of a projectile. The use of tracer shells, especially in night firing helps control the direction of fire.

Weapon: A device for inflicting damage upon the enemy by projecting missiles and ammunition.

Zone Fire Charge: A system of loading semifixed and separate load propellant powder into a series of bags so that, in the field, the number of bags being used to fire a projectile can be changed to adjust the range of fire of a weapon.

Footnotes:

1) Tschappet, William, Textbook of Ordnance and Gunnery (New York: John Wiley and Sons, 1917).

2) idib., p.4.

3) Hayes, Thomas J., Elements of Ordnance, New York: John Wiley and Sons, 1938.