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ALLIED and ENEMY EXPLOSIVES,

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(10) Basil T./Federoff

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PREPARED UNDER THE DIRECTION OF
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CHAPTER 1

SECTION I

INTRODUCTION

In this war 85% of the casualties have been caused by high explosive ammunition. This means that we are primarily engaged in destroying the enemy by the proper use of as much high explosive as it is possible to dump on him.

Therefore, practically everyone in the Army is called upon to handle explosives at some time during their Army career and, for their own safety, all personnel should have some knowledge of the characteristics of explosives. It follows that, knowing these characteristics, the reason for and the observance of the proper safety precautions should be automatic.

This premise is particularly true of bomb disposal personnel whose routine job is complete disposal of all ammunition, Allied and Enemy. The complete disposal, of course, includes the explosive components of ammunition. Therefore bomb disposal personnel should be especially familiar with the characteristics of all explosives they may be required to destroy.

Having identified an explosive, the B.D. officer will need to know what its behavior will be under all conditions, the precautions which must be observed in dealing with it and the safest means by which it may be destroyed. He will also be better equipped to make an intelligent report concerning new and unidentified explosives.

Fundamentally there is little use in safely defuzing ammunition if the explosive is mistreated through ignorance and a premature detonation results.

[redacted]

This p~~h~~amphlet ~~will~~ gives a short introduction on the fundamental nature of explosives followed by an analysis of the characteristics of all Allied and Enemy explosives which may be encountered in the field. If some of this material seems to be of the "nice to know" type it should be remembered that, when discussing any subject, it is necessary to build up a background and vocabulary to permit intelligent communication, using commonly understood terms.

SECTION II

DEFINITION OF TERMS USED

1. AN ATOM is the smallest portion of any matter.
2. A MOLECULE is the smallest particle of any kind of substance that can exist independently and still have the same properties as the original substance. It is composed of atoms.
3. A REACTION is the mutual action of chemical agents or some distinctive result of such action.
4. KINDLING TEMPERATURE is the temperature necessary for the reaction of two agents.
5. OXIDATION is the reaction of a combustible material with oxygen to form a gas.
6. COMBUSTION is rapid oxidation accompanied by flame. It is commonly called burning or deflagration.
7. FLAME is a product of combustion and is caused by heating minute particles of solid matter to an incadescent heat.
8. DECOMPOSITION takes place when the atoms of a molecule separate and do not reunite after the disturbing cause has ceased to operate.
9. EXPLOSION is rapid decomposition and the term is generally used in describing the action of low explosives.

10. DETONATION is the rapid decomposition of a high explosive.

11. HEAT OF COMBUSTION is the total heat evolved when a definite quantity of substance is completely oxidized.

12. EXUDATION is the act of sweating out of liquid through the pores of solid material.

13. HYDROLYSIS is a double decomposition in which water is one of the interacting substances.

14. A FUZE is a device used to function ammunition.

15. A FUSE is a device used to function charges of explosives.

CHAPTER 2

SECTION I

TYPES OF EXPLOSIONS

An explosion may be defined as the sudden and rapid escape of gases from a confined space accompanied by high temperatures and a loud noise.

There are two types of explosions, mechanical and chemical. A good example of a mechanical explosion is the case of the steam boiler. The water is heated and converted into steam which fills the boiler, gradually increasing the pressure. When the boiler can no longer contain the pressure it bursts, with a loud noise, permitting the gas (steam) to escape.

It should be noted that in this case, pressure was gradually increased to a maximum causing the explosion, following which the pressure returned immediately to that of the atmosphere.

Chemical explosions are radically different from this. If a stick of dynamite is detonated the explosion occurs and gases expand reaching a maximum pressure after, and as a result of, the detonation. After this they gradually return to atmospheric pressure. For military purposes we need only consider chemical explosions.

SECTION II

PRINCIPLES OF EXPLOSIVE ACTION

Explosives generally function by a rapid expansion, from a solid form, to gaseous products which occupy a much greater volume. This expansion is the result of several factors:

1. The first of these is the reaction of combustible with oxygen to form a gas. Everyone is familiar with the burning of wood or coal in the atmosphere. In this reaction the carbon and hydrogen in the

wood or coal combine with the oxygen in the atmosphere to form Carbon Dioxide and Steam together with flame and smoke. The smoke consists of unoxidized particles in suspension in the atmosphere and the flame is caused by other particles, heated to an incadescent heat.

If the wood or coal is pulverized so that the total surface in contact with oxygen is increased and is burned in a furnace or forge, where more air is supplied, the burning is more rapid and the combustion more complete.

If the wood or coal is immersed in liquid oxygen or suspended in air, in the form of dust, the burning takes place with explosive violence.

In each case the action has been the same, the burning of a combustible in oxygen to form a gas. The only difference is the speed with which the reaction took place.

This leads us to the principle that any material that will burn can be made to explode if enough oxygen is supplied rapidly enough.

This is demonstrated by the explosion in our internal combustion engine where combustible mixtures of gasoline and air explode running the engine.

In coal mines Methane Gas and coal dust combine with air to produce explosive mixtures and in grain elevators minute particles of dust form explosive mixtures with the air.

Our Military explosives are based on this principle except for the fact that they contain their own oxygen and so are independent of oxygen supplied [illegible]. They are simply mixtures or compounds of combustibles with enough oxygen to insure complete combustion.

2. The second factor is the evolution of heat during the reaction. It is heat which causes the gases to expand after they are formed.

[illegible]thout heat the oxidation of an explosive would be no more effective than the burning of wood or coal. For example, Nitric Acid and Sodium Carbonate will react to form gases but the reaction does not evolve heat and so it is not an explosive reaction.

3. The third factor is the rapidity of reaction. Unless the reaction occurs rapidly the heat expanded gases will be dissipated in the atmosphere and will not explode. Here again we can consider our wood or coal fire. We have evolution of heat and formation of gases but not rapidly enough to cause an explosion.

4. The fourth factor is the requirement that the explosive readily undergo rapid reaction from the application of energy, in the form of shock or heat, to a small portion of its mass. Obviously a material, in which the first three factors exist, is not suitable as an explosive unless we can readily put the factors into operation.

These four factors are inter-dependent and are operative in the functioning of all explosives with the exception of a few Metallic compounds, such as Lead Azide, which do not undergo combustion but depend on a rapid expansion of hot Nitrogen Gas.

This brings us to a formal definition of an explosive:

An explosive is any gaseous, liquid or solid substance or mixture of substances, which, when subjected to shock or heat, decomposes rapidly and with great heat into other more stable substances, mostly gaseous, many times the original volume.

SECTION III

TYPES OF EXPLOSIVES

1. GENERAL.

There are two things that can happen to an explosive. It can undergo combustion or it can decompose.

When we speak of undergoing combustion we mean that it will burn when ignited in the open air utilizing the oxygen in the atmosphere for combustion. This is a comparatively slow process and can be watched with the naked eye. Practically all explosives will undergo this reaction except Primary High Explosives. It is of interest to B.D. personnel from the standpoint of destruction of explosives.

Chemical decomposition may take place in years, days, hours or in a fraction of a second. The slower forms of decomposition take place in storage and are of interest from a stability standpoint.

The rapid forms of decomposition are Explosion and Detonation. Low Explosives explode when confined and High Explosives detonate whether confined or not.

2. LOW EXPLOSIVES.

Low or Deflagrating Explosives are those materials which undergo rapid decomposition by burning from the surface inward. They are usually manufactured in grains and used as propellants.

Let us assume that a number of grains of Smokeless Powder are placed in the breech of a gun. Sufficient heat is applied so that the powder will ignite. That is a temperature will be attained which will cause the combustibles to react with the self-contained oxygen to form gas and liberate heat. Since this heat cannot escape, because of the confinement of the breech, it will heat up the next layer of powder exposed by the burning away of the original surface layer and increase the expansion of gases. This continues until the grain is completely consumed and concurrently each grain ignites adjacent grains until the entire charge is consumed. These individual grains burn from the outside toward the center at the rate of five feet per second compared with 0.01 feet per second in the open.

As the burning continues through the charge, the pressure and heat rise and the burning becomes more and more rapid. The rate of burning is doubled for every 10°C rise in temperature.

This form of decomposition is usually termed an Explosion and proceeds comparatively slowly, explosively speaking. The result is a heaving or pushing effect which makes the explosion valuable as a propellant. It is of little value as a bursting charge because the gases would be dissipated in the atmosphere before they could reach a maximum pressure and be directed against the objective. In the barrel of a gun however, the shell will begin to move before expansion is complete, leaving room for more expansion and preventing the barrel from bursting.

3. HIGH EXPLOSIVES.

High or Detonating Explosives decompose almost instantaneously by a rupture or splitting of the molecule and the rearrangement of the atoms into other molecules, mostly gaseous.

High Explosives are compounds made up of a number of molecules. Each molecule is in turn made up of Carbon, Hydrogen, Nitrogen and Oxygen atoms tied together by forms of energy called bonds. Whil Carbon and Hydrogen tend to unite with Oxygen, Nitrogen has no affinity for these atoms but tends to return to the atmosphere of which it comprises 80%. The result is a rather unstable molecule which tends to revert to a more stable state.

The term detonation is used to describe the phenomenom which takes place when a High Explosive explodes. There are several theories as to the mechanics of detonation but the following seems most logical.

Detonation takes place in two phases, a spliting of the molecules followed by an almost instantaneous burning. The first phase is initiated by supplying enough energy, usually in the form of shock, to an explosive so that the disruptive forces within the molecule exceed the attractive forces between the atoms and decomposition is started.

The tendency toward disruption is caused by the desire of Nitrogen to go back into the atmosphere and any abnormal arrangement of the bonds holding the atoms together. The attractive forces are the normal bonds tying the atoms together. These bonds are a form of energy. When they are broken the energy is released in the form of a pressure wave of high temperature, the shock of which disrupts adjacent molecules.

If the initial energy is sufficient this wave will proceed thru the entire mass of explosive until it has completely detonated, provided the energy released by the splitting of one molecule is sufficient to decompose adjacent molecules. The pressure wave is quite often completed before the second phase of detonation has had any material effect. Photographs of dynamite cartridges have shown the first phase completed before the cartridge paper has even been disrupted. It delivers a terrific hammer-like blow to any object in its path. It is important to take advantage of this form of energy in B.D. demolitions.

The second phase of detonation consists of the formation of gas molecules. When the original molecule is split the heat of the detonating wave causes the Carbon and Hydrogen atoms to reach an ignition temperature at which point they unite with the Oxygen atoms to form the gases Carbon Dioxide and Water Vapor along with other gases which may result from an Oxygen deficiency.

This action is accompanied by great heat which causes the gases to expand in all directions.

Detonation takes place almost instantaneously and causes a disruptive effect which is very valuable in a bursting charge. The speed of action causes the gases to reach a maximum pressure and be delivered against the objective before they can be dissipated in the atmosphere. High Explosives cannot, however, be used as propellants as the pressure developed would burst the barrel of the gun before it overcame the inertia of the shell.

In summary we might say that Low Explosives can undergo combustion; can decompose slowly or explode. High Explosives can undergo combustion (except Primary High Explosive) can decompose slowly and can detonate. High Explosives may be treated so that they will explode but Low Explosives will never detonate.

In the case of High Explosives no confinement is necessary to cause detonation. Atmospheric pressure affords sufficient confinement.

SECTION IV

RESULTS OF DETONATION

High Explosives detonate at temperatures of 3000 to 4000°C, expanding to 10,000 to 15,000 times their original volume at speeds up to five miles per second, exerting pressures of 1,000,000 pounds per square inch and up. Such figures are rather astronomical and a better idea of the power of these explosives can be given by referring to Quarry Blasting. Here one pound of dynamite is usually figured to displace a minimum of three tons of rock. From this it can be seen that High Explosives, even in small quantities, can cause considerable destruction.

When a High Explosive bomb detonates the effects may be divided into several phases:

1. The expanding gases cause the case to swell to twice normal

size at which point it ruptures and the fragments are propelled with the speed of a rifle bullet. This phase is known as Fragmentation Effect.

2. The second phase is called the Blast Effect and it in turn consists of several phases:

a. The detonation wave delivers a hammer-like blow which is very destructive to anything in its path. In water it is this blow which springs the plates of ships.

b. Following the detonating wave, the expanding gases reach a maximum pressure in a fraction of a second and then rush away from the point of detonation at the rate of about 7000 miles an hour gradually cooling and subsiding until they are dissipated at a distance of 50 to 100 feet from the bomb. In doing this they will demolish everything in their path.

c. This rush of gases sets up a compression wave in the surrounding medium whether it be air, water or earth.

In the air, an artificial gale is set up whose initial velocity is about 7000 miles per hour. The air acts like an accordion, successive layers being compressed and expanding until the wave gradually dies down. This action is generally called Concussion. In the water and earth the same type of movement takes place and is called Earth and Water Shock.

In the air the concussion will do terrific damage sometimes for considerable distances. In the ground earth movement will destroy foundations and utility installations.

In the water the shock travels faster and farther and with a much higher pressure but it is of shorter duration. It is very damaging to the plates of ships.

d. As the expanding gases cool and subside, after displacing the atmosphere, a partial vacuum is created. This is of longer duration than the positive phase but not as destructive. The pressure of air in surrounding buildings, attempting to fill the vacuum, will cause weakened walls to collapse. This phase will be destructive around corners and back of barriers while the positive phase is only effective in a straight line.

3. Because of the high temperatures produced, all explosions have an incendiary effect on everything combustible at and near the point of explosion.

SECTION V

DISCUSSION OF CHARACTERISTICS OF EXPLOSIVES

1. SENSITIVITY

The term "Sensitivity" as applied to explosives means the ease with which they may be ignited or detonated or, in other words, the amount of shock, friction or heat required for ignition or detonation.

Basically the question as to whether an explosive is sensitive or not, depends on the fundamental makeup of the explosive itself.

Some explosives, such as Lead Azide, are endothermic in nature. That is, they absorb heat during formation and release it during decomposition. Because they contain stored up energy, they are very sensitive and very little energy need be supplied for their decomposition.

The sensitivity of this type of explosive is also increased by the manner in which the atoms are tied together. Lead Azide, for instance, not only has Nitrogen atoms tied together, thereby enhancing their antisocial nature, but by double bonds as well making the entire molecule very unstable.

On the other hand certain explosives, such as TNT, are exothermic in nature. They give off heat during formation and take up heat during decomposition so they must be supplied with considerable energy for decomposition.

There are, however, certain factors which will affect this basic sensitivity of explosives. They are:

A. Crystal size - The sensitivity of the endothermic type of explosive, which is made up of unbalanced molecules which are held together by forces which are under uneven strains, is increased by larger crystals which increase the internal friction and strain.

B. Density - When the explosive crystals are loaded at high density the mass resists penetration by the hot gases which cause detonation. Therefore the higher the density the lower the sensitivity. Mercury Fulminate, for example, becomes dead pressed and will not detonate from flame.

C. Temperature - Since all explosives will detonate from heat, as the temperature approaches this point the explosive becomes more sensitive.

D. Moisture - Since moisture is inert and exercises a cooling effect, by absorbing heat, its presence will reduce sensitivity.

E. Coating of crystals - If the crystals are coated with wax they are cushioned from shock and the friction between crystals is reduced. This decreases sensitivity.

F. Crystal Distortion - If the crystalline structure is distorted and intercrystalline friction increased the explosive may become more sensitive. This may be caused by high speed compression or by melting and cooling.

2. VELOCITY OF DETONATION

When a High Explosive detonates the action proceeds in a wave throughout the column of explosive. The rate of speed with which this wave progresses is termed the velocity of detonation and is usually expressed in meters per second.

Under the same conditions, different explosives detonate at different velocities because of their Nitrogen content. Nitrogen, being unstable, causes the explosive to be more easily detonated and this tends to increase the speed of detonation.

There are certain factors which materially affect the velocity of detonation. They are:

1. Loading Density - Velocity increases with the increase of density because the continuity of the material is increased and the detonating wave does not have to jump gaps in the explosive. This is true up to a critical density point at which the velocity decreases and the detonating wave may not propogate. This is caused by attaining so dense a mass that the hot gases cannot penetrate readily. As proof of this let us consider the velocity of PETN at various densities:

DENSITY	VELOCITY
.45	3510
.75	4820
.91	5300
1.04	5730
1.45	7375
1.72	8050

2. Diameter of the Column - The detonation wave traveling on a spherical front through the column of explosive is a form of energy.

When the diameter of the column is small the exposed surface is larger in comparison with the total volume. Therefore the percentage of surface energy is large in comparison with total energy available. As a certain part of this energy is subject to dissipation in the atmosphere it can be readily seen that with a comparatively large percentage of energy lost, there is less energy left to continue the detonating wave than if the column were larger in diameter and the mass of explosive could act as a confining agent. In this case the surface and hence the percentage of energy dissipated are small compared with total energy available and therefore there is more energy left to be directed against undetonated portions of the mass and the result is a more rapid detonation. Primacord Detonating Fuse is a good example of this effect. Primacord, which contains a small column of PETN, detonates at 6200 meters per second while PETN can attain a velocity of 8300 meters per second.

3. Confinement - Because confinement prevents this surface dissipation of energy it also increases the velocity of detonation.

4. Length of Column - When explosives detonate, the velocity is increased until it reaches a maximum and then continues at this rate until detonation is complete. Therefore it is necessary to have a column sufficient in length for the explosive to attain maximum velocity.

5. Presence of Moisture - Moisture is inert as far as the detonation is concerned and also exercises a cooling effect. Therefore it reduces the velocity of detonation.

6. Coating the Grains - The use of wax to coat the individual grain introduces an inert material which will not detonate and at the same time cushions the shock making detonation more difficult and

thereby reducing the velocity.

7. Temperature - An increase in heat makes the explosive more sensitive thereby facilitating detonation and slightly increasing velocity.

8. Grain Size - An increase in the grain size decreases velocity due to the fact that, with large grains, there is incomplete development of energy at the time of passage of the detonating wave.

9. Power of the Initiator - Every explosive requires an initiator of a certain minimum power to insure a High Order Detonation and this varies with each explosive. Initiators of abnormal strength, while they may increase velocity initially, will not detonate an explosive at a greater than maximum velocity for that explosive. In other words if .24 grams of Mercury Fulminate are necessary to detonate TNT it dosen't make any difference whether one pound or 2000 pounds of TNT are detonated, the requirement would still be .24 grams of Mercury Fulminate. In actual practice larger amounts are used but this is a cheap form of insurance when using large amounts of explosive.

3. STRENGTH

The strength of an explosive is its ability to do work.

The strength of an explosive may be measured from two standpoints. From an execution standpoint it is the ability of the explosive to displace the medium which confines it. From a laboratory standpoint it is the amount of energy liberated by the explosion or detonation. Actually the amount of energy liberated determines the amount of displacement which will take place.

There are two factors governing the amount of energy liberated. They are gas volume, and heat of explosion. The gas volume is controlled by the completeness of oxidation. An explosive which oxidizes completely to Carbon Dioxide and Water Vapor releases more gas than one which also decomposes to Carbon Monoxide, Methane and Carbon. Therefore it is desirable to provide the explosive with enough oxygen for complete combustion.

Because there is 1/273 increase in volume for each degree of rise in temperature, the heat of explosion is of primary importance. It is the heat which expands the gases after they are formed. Other factors being equal, the explosive liberating the most heat will have the most strength.

Certain explosives, such as Lead Azide, will develop a fair amount of energy due to the heat of explosion, in spite of the fact that no oxidation takes place.

Heat of explosion is increased by complete oxidation so the process runs in a circle. The more gas the more heat and the more heat the greater the expansion of gases which means the greater the energy and strength.

4. BRISANCE

When a force displaces a mass through a distance the result is work done. This, as we have seen, is determined by the strength of the explosive.

When the time element is considered with respect to work done we use the term Power (sec).

Explosives have both strength and power but they also possess a third characteristic which is shattering effect or brisance (from the French meaning to break). This is a unique characteristic of explosives.

When an explosive detonates tremendous pressure is released practically instantaneously in a wave which exists for only a fraction of a second at any given spot. The subsequent expansion of gases performs work but this pressure wave will shatter, rather than displace any object in its path.

This shattering effect or brisance, has a direct relationship to velocity and can be calculated with a small margin of error by using the equation:

$$\text{Log of Brisance} = 3.53 \times \text{Log} \frac{\text{Velocity}}{2500}$$

5. POWER

Power may be defined as the rate of doing work. This definition applies to an explosive as well as any other form of energy.

It is dependent on strength and velocity, the amount of energy released and the speed with which it is released.

Strength, Brisance and Power are closely related. Generally speaking of two explosives of equal strength the one detonating at the highest velocity will not only have the greatest brisance but will be more powerful. It will be more brisant because of the sharpness of the blow and more powerful because of the speed with which the energy is delivered.

Of two explosives of equal velocity the stronger will be more Brisant because there is more weight back of the blow. It will be more powerful because more energy is delivered in the same time, It is possible to increase velocity and reduce strength thereby increasing both brisance and power and it is also possible to reduce velocity, somewhat, and by greatly increasing strength to increase both brisance and power.

In the first case brisance is increased by the sharpness of the blow and power by the increased speed with which the blow is delivered.

In the second case both power and brisance are increased by the weight of the blow in spite of the fact that the time of delivery is increased.

Power is usually measured in terms of sustained impulse which is equal to one half the peak pressure multiplied by the duration of the positive phase.

6. HIGH ORDER OF DETONATION.

This is a complete detonation at maximum velocity. All the explosive detonates at the highest velocity possible under existing conditions. .

7. LOW ORDER OF DETONATION.

This is either incomplete detonation or complete detonation at lower than maximum velocity. It can be caused by:

1. An initiator of inadequate power.
2. Deterioration of the explosive itself.
3. Poor contact with the initiator or lack of continuity in the charge itself caused by:
    a. Low density.
    b. Exudation.

8. DENSITY.

Density is the weight per unit of volume. In giving density figures the density is compared with water. In the Metric System one cubic centimeter of water weighs one gram, therefore, if we give the density of an explosive as 1.5 we mean that one cubic centimeter weighs 1.5 grams. This is also its specific gravity compared to water.

Density is important in the reaction of explosives. By making it more difficult for gases to penetrate the explosive mass, it reduces sensitivity. By increasing the continuity of the explosive mass it increases velocity.

It also makes a more solid load thereby decreasing the tendency for cavities to form. These may cause misfires or premature detonations (see loading).

In addition, increased density will permit the use of more explosive in the space provided thereby increasing the efficiency of the ammunition. For example if we have two explosives of equal power per pound and the first has a density of 1.0 and the second a density of 2.0 we can load twice the amount of the second in the same space as the first thereby doubling the efficiency of the ammunition.

9. STABILITY IN STORAGE.

Quite often the term "stability" is used to mean the opposite of sensitivity. From a Military standpoint, however, it is used to indicate stability in storage or the ability of the explosive to stand storage, under all conditions, without deterioration.

The fact that a material is very sensitive does not imply that it is unstable in storage nor does the fact that it is insensitive mean that it will be stable in storage. A substance may be extremely reactive chemically but at the same time it is stable in the absence of anything with which to react.

For example, Lead Azide may explode from a slight shock but is entirely stable if left alone while Nitrocellulose requires a powerful detonator but is subject to spontaneous combustion.

Stability is affected by the following factors:

1. Chemical Constitution - Certain explosives, such as the Nitrates will decompose at ordinary temperatures. This is due to the molecular structure and nothing can be done about it except to modify the reaction.

2. Temperature of Decomposition - If the above type of reaction evolves heat the reaction will be accelerated and spontaneous combustion may result.

3. Temperature of Storage - Certain explosives, such as Mercury Fulminate, are stable at ordinary temperatures but will decompose at elevated temperatures.

4. Reaction of Decomposition-Products - The products of decomposition may accelerate the reaction or they may start a new reaction. For example, Ammonium Nitrate will hydrolize to Ammonia which will then react with TNT.

5. The Presence of Impurities - Impurities have a tendency to make the Aromatics unstable. For example, impurities lower the melting point of TNT causing exudation.

6. Presence of Moisture - This will affect many explosives such as Black Powder and Ammonium Nitrate.

7. Exposure to Sun - The direct rays of the sun will decompose all Nitro compounds.

10. HYGROSCOPICITY.

Hygroscopicity is the tendency of a material to absorb moisture. It affects explosives by the introduction of an inert material which will also absorb heat.

Since inert materials reduce the continuity of the explosive mass and since cooling reduces the temperature of reaction it is easy to see that moisture will reduce sensitivity, strength and velocity. In the case of Ammonium Nitrate Explosives, it may even cause the explosive to become so insensitive that it will not detonate.

In addition, the presence of moisture will often cause decomposition thereby affecting stability and leading to corrosion of metals.

11. THE CAVITY EFFECT.

The Cavity Effect, also known by the names; Munroe Effect, Neumann Effect, Shaped Charges and Hollow Nose Ammunition was originally noticed by Baader of Norway in 1799. Since then many men of many nationalities have experimented with it.

Munroe, at the Newport Naval Torpedo Station in 1888 and Neumann in Germany in 1910, gave it considerable publicity and it frequently bears their names for that reason.

The principle of the effect can be summarized as follows: When two or more explosive waves meet at an angle they reinforce each other. The result is the combining and focusing of the lines of force into a jet, the force of which is greater than any one of the component forces. The effects of this jet are more pronounced when the charge is held away from the objective.

As we have seen the detonation of a high explosive consists of two phases; first the detonation wave or shock wave itself which proceeds in a wave through the column of explosive and exerts tremendous directional force and second the subsequent expansion of gases which follows the lines of least resistance.

Let us now assume that we place a solid block of explosive on a steel plate and initiate it in the direction of the plate. The detonating wave will indent the plate due to its directional force but the gases, following the lines of least resistance, will escape into the air without materially affecting the plate. If we take the same block, cut a cone into the base, line the cone with metal, hold the cone away from the plate and initiate the charge in the direction of the plate we utilize the Cavity Effect.

As the detonating waves from both sides of the cone, traveling on a spherical front, meet in the hollow portion of the cone they reenforce each other and are focused into a jet which is driven with terrific force (about 200,000 atmospheres) into the plate, at right angles to their intersecting fronts. Simultaneously the metal liner is chipped and the fragments enter the jet and form part of it.

Following this the lines of force from the explosive gases, which expand in the cone as well as into the surrounding medium, also re-enforce each other and are focused towards the plate, collapsing the liner into a slug in the process. These forces with the slug enter or pass through the hole made by the jet.

The jet heats the metal to a state of incandescence pressing it outward as it progresses. The secondary force continues this process, enlarging the hole.

While the Cavity Effect has been well known for years its practical application is still in the experimental stage and no iron bound rules can be given for its use. Each type of ammunition incorporating the principle has been developed by trial and error. However the following factors seem to apply and must be considered in developing the ammunition:

A. Diameter of the Cone - This varies directly with the size of hole to be cut. The three principle diameters now in use are 2¼" for the 42½° cone (Bazooka cone), and 1" and 3" for the 80° cone.

B. Thickness of the Liner - A thickness of 3% of the diameter for an 80° cone seems best.

C. Angles of Cones - The conical shaped liner gives a deeper hole with smaller diameter and less stand-off distance. This principle utilizes a smaller charge. An 80° cone seems most effective.

D. Material of Liner - Mild steel seems most effective.

E. Stand-off - This is accomplished by collapsible legs, in the case of demolition charges, and a hollow ogive in the case of shells and bombs.

The stand-off distance increases with the angle of the cone. In using a small angle the detonation waves, which proceed approximately perpendicularly from the sides of the cone, will form a jet more quickly than if a wide angle is used. The difference in stand-off will give these waves time in which to form the jet.

Typical stand-off distances are:

1. For $42\frac{1}{2}^{\circ}$ cone	1 diameter
2. For 80° cone	1 to 2 diameters
3. For 120° cone	3 to 4 diameters

F. Loading Density - This affects velocity and unit power and hence the effectiveness of the charge.

G. Method of Initiation - The charge should be initiated directly over the apex of the cone to give an even detonation wave and to utilize the directional force of the wave.

H. Kind of Explosive - It should be noted that the above specifications are for demolition charges using, RDX based, plastic explosives. It is quite probable that, using other types of explosives, changes in these specifications would be made.

The Cavity Effect is being used by all nations in this war in shells, bombs, torpedoes, and demolition agents. Some of the specific uses follow:

A. United States

1. Bazooka - Muzzle Velocity 265 feet per second: Will penetrate 3" of armor plate and 8" of concrete: Filled with composition C_2 or Pentolite.

2. Anti-tank Rifle Grenade

3. Demolition charge T3 - Weight, 35 pounds: Filled with 50/50 Pentolite: Will penetrate 5 ft. of concrete.

B. Britain

1. Beehive Demolition Charge - Weight 6 lbs. of TNT: Will penetrate 2'9" of concrete.

2. Beehive Demolition Charge - Weight 75 lbs.: Will penetrate 5 ft. of concrete.

C. Germany

1. Bombs -250 Kg: Will penetrate 14" of armor plate.

500 Kg: Will penetrate 24" of armor plate or 11½" of concrete.

800 Kg: Will penetrate 40" of armor plate or 20" of concrete.

2. Demolitions - 12½ Kg. charge: Will penetrate 4-3/4" of armor plate.

Ammunition incorporating the Cavity Effect is often referred to as Armor Piercing ammunition but this is not true in the accepted sence of the word. This ammunition causes a scaling and blast, or concussion, effect, on the objective by a tremendeous concentration of force on a small area as follows:

A. On Armor Plate - The metal is heated to a state of incandescence and particles fly from the back of the plate in a cone shaped spray causing an anti-personnel effect. The spray will usually detonate ammunition. In addition to this, the terrific blast effect will kill anyone back of the plate, as in a tank.

B. On Concrete - The explosion will not melt the concrete but will cause the scaling and concussion effect, described above, on a concrete pillbox.

SECTION VI

COMMON INGREDIENTS

1. AROMATIC HYDROCARBONS

The Aromatic Compounds have been and are still the principle raw materials from which most explosives are manufactured. They are largely derived from coal tar which is obtained by coal coking.

Coal yields 6% of its weight in tar. One ton of tar on distillation yields:

Light Oil	(32 pounds of Benzene (5 pounds of Toluene (0.6 pounds of Xylene
Middle Oil	(40 pounds of Phenol and Cresol (80-120 pounds of Napthalene
Heavy Oil	(Impure Cresols and Other Phenols
Green Oil	(10-40 pounds of Anthracene
Residue	(1000-1200 pounds of Pitch

Napthalene is the most abundant hydrocarbon and nitrates easily but is not powerful enough to be used as an explosive.

The Phenol-Cresol combination yields Phenol for Picric Acid, on distillation, but it is cheaper to use the Chlorobenzene process. (see)

Cresol explosives are not powerful enough.

Benzene is difficult to nitrate and although this has been solved by the Chlorobenzene Process the operation still involves more steps and therefore is more expensive than the nitration of Toluene.

This leaves Toluene which is easily and cheaply nitrated, is fairly plentiful and has the proper explosive properties. For these reasons TNT has been the standard explosive since 1904. The others are reserve explosives which are used because of their more plentiful raw materials.

Coal tar occurs naturally in Borneo Petroleum which has been a Godsend to the Japs.

The United States is now obtaining Toluene in large quantity from Petroleum Cracking which explains our enviable position with regard to TNT in this war. The Axis, lacking a petroleum industry, has to fall back on substitutes.

2. NITRIC ACID HNO_3

In order to make the Aromatic Hydrocarbons into explosives it is necessary to do two things. In the first place they have to be supplied with Oxygen for combustion otherwise no gases will be formed. In the second place they have to be made chemically unstable so they will detonate. The nitration of the material with Nitric Acid fulfills both requirements.

Nitrogen, which is obtained from the atmosphere, is anti-social in nature. It violently objects to forming compounds with other atoms and breaks away at the least provocation. The detonation of a compound containing Nitrogen is a violent reaction in which the Nitrogen breaks out of the compound and in so doing causes it to fly to pieces with the liberation of much of the energy absorbed in manufacture. In Nitric Acid this characteristic of Nitrogen is enhanced by the presence of two Oxygen atoms tied together.

Therefore, the nitration process not only converts the material into an explosive but introduces Oxygen for combustion.

3. SULPHURIC ACID H_2SO_4

Usually the nitration is carried out with mixed acid, a combination of Nitric and Sulphuric Acid. The function of the latter is to absorb water produced in manufacture and to prevent dilution of the Nitric Acid.

4. ALCOHOLS

Methyl and Ethyl Alcohol are widely used as fuels, in the manufacture of explosives, in the place of the Aromatic Hydrocarbons.

Methyl Alcohol is now made synthetically and is the basis for Formaldehyde, one of the basic ingredients of PETN AND RDX. Ethyl Alcohol is made in large quantities from grain.

5. AMMONIA NH_3

Ammonia is a very important explosive ingredient. It has many uses but the chief ones are in the manufacture of Nitric Acid and the Nitro-Amines, the latter being a very powerful group of explosives which includes Tetryl and RDX. It is also nitrated to Ammonium Nitrate (see).

6. OXIDIZING AGENTS

Most Military Explosives are deficient in Oxygen so it is often necessary to add oxygen, in order to increase the completeness of combustion, thereby changing Carbon Monoxide to Carbon Dioxide. The latter develops 2½ times more heat than the former.

The following is a list of the more common oxidizing agents with the percentage of Oxygen made available for combustion:

NITRATES	Potassium Nitrate KNO_3	- 39.5
	Sodium Nitrate $NANO_3$	- 47.0
	Calcium Nitrate $Ca(NO_3)2$	- 49.0
	Barium Nitrate $Ba(NO_3)2$	- 31.0
	Lead Nitrate $Pb(NO_3)2$	- 25.0
	Ammonium Nitrate NH_4NO_3	- 20.0
CHLORATES	Potassium Chlorate $KClO_3$	- 39.0
	Sodium Chlorate $NaClO_3$	- 45.0
PERCHLORATES	Potassium Perchlorate $KClO_4$	- 46.0
	Sodium Perchlorate $NaClO_4$	- 52.0
	Ammon. Perchlorate NH_4ClO_4	- 34.0

The nitrates, except Ammonium Nitrate, are non-explosive in nature being based on metals which do not enter into the reaction. Therefore they will decrease the strength and velocity of the explosive on a weight or volume basis. For example, suppose we had a mixture of 50/50 TNT/Potassium Nitrate. Potassium forms approximately 40% of the weight of the KNO_3 and 20% of the mixture. Therefore 20% of the explosive is inert.

Among the Nitrates, Sodium Nitrate liberates the most Oxygen and is cheap but it is also hygroscopic so its use is confined to explosives such as Blank Fire powder where hygroscopicity is not so important.

Potassium Nitrate is less effective and more expensive but it is also less hygroscopic so it is used where uniformity is important e.g. Fuse Powders.

Calcium Nitrate is a cheap, very hygroscopic agent and is used by Germany due to raw material shortages.

Barium Nitrate is non-hygroscopic and non-corrosive. It is used in non-corrosive primers. As it is a less effective agent it is sometimes used to retard the burning speed of Fuse Powders.

Lead Nitrate is inefficient and very seldom used except in long delay Fuse Powders.

The Chlorates and Perchlorates have the property of liberating their Oxygen with great violence when mixed with an impurity such as a combustible. They do this from the slightest shock or friction. The Perchlorates are slightly less sensitive than the Chlorates. Both have been used in the past in dynamite type explosives called Cheddites. These proved to be too sensitive and unstable but they are still used abroad to some extent. (See Chlorate Explosives.)

Potassium Chlorate has the most application in Military Explosives. It is widely used with Antimony Sulfide (see) as a percussion cap in

Artillery Ammunition and is present in most Fuze Primer Mixes. It increases the heat of explosion without lowering the sensitivity of the Primer.

Sodium Chlorate is too hygroscopic and the Perchlorates too insensitive for this purpose. Potassium Chlorate yields Potassium Chlorides which corrode steel in the presence of moisture. For this reason, Barium Nitrate is used in non-corrosive primers.

7. AMMONIUM NITRATE NH_4NO_3

Ammonium Nitrate is an explosive which is so insensitive that it cannot be detonated by ordinary shock but requires a high explosive primer. It develops 75% of the strength of Nitroglycerine and for this reason is very important, being the principle explosive ingredient in commercial dynamites and an extender for TNT in military explosives. It is a cheap and abundant explosive and enables us to carry on commercial blasting and warfare on the present day scale.

As it liberates 20% of its Oxygen for combination with combustible materials it is also used as an oxidizing agent. It differs from other oxidizing agents in that all of its ingredients are active, consisting of Nitrogen, Hydrogen and Oxygen.

The TNT or Nitroglycerine, which coat the Ammonium Nitrate crystals, carry the detonating wave from the primer causing the Ammonium Nitrate to decompose explosively, producing Nitrogen, Steam and Oxygen. The latter enters into a further explosive reaction with any combustible material present.

Ammonium Nitrate is white but discolors rapidly from contact with the atmosphere. It is manufactured synthetically. Hydrogen is obtained from water gas and is burned in air forming Nitrogen. Nitrogen and Hydrogen are mixed and treated to form ammonia gas which neutralizes

Nitric Acid to form Ammonium Nitrate.

The velocity of detonation of Ammonium Nitrate varies from 1400 meters per second to 5500 meters per second depending on the grain size. The smaller the grain the higher the velocity.

It has a melting point of 155° to 170°C and decomposes at 210°C.

It is very hygroscopic and will corrode metals especially if moisture is present. It is soluble in water and Acetone.

Ammonium Nitrate represents a large supply of cheap explosive material which also acts as an oxidizing agent to a limited extent. Its disadvantages are its lack of stability in storage and its low velocity of detonation.

8. ALUMINUM

Aluminized explosives in the form of Ammonals (TNT, Ammonium Nitrate and Aluminum Powder) were used in the past but not to any great extent due to the high cost and limited availability of Aluminum and the lack of instruments to properly measure blast effect caused by the addition of Aluminum.

These drawbacks have been overcome and the present trend is toward the use of Aluminized Explosives. Aluminum has an affinity for Oxygen and will extract Oxygen from the air or water or from any other medium in which Oxygen is present. When Aluminum combines with Oxygen it forms Aluminum Oxide and intense heat which increases the heat of detonation, the expansion of gases and hence the strength of the explosive.

Aluminized Explosives should not be used when penetration and detonation below the surface of the ground are desired because the Aluminum will rob the explosive of its Oxygen and cause an incomplete combustion and hence a reduction in the gas volume and strength. For under water or aerial burst Aluminum will extract the Oxygen from the water or air without robbing the explosive. Because Aluminum is inert, as far as the actual detonation is concerned, it will reduce the velocity of detonation and hence the brisance of the explosive so that it gives best results when added to very fast explosives such as RDX and in the proportion of 18 to 20%.

Because of its affinity for Oxygen and the fact that it is undergoing continual oxidation, Aluminum is essentially unstable and increases the sensitivity of explosives in which it is included. It will also increase formation of Ammonia in combination with Ammonium Nitrate and water (see Ammonals). The following table will compare the heat and gas volumes of regular and Aluminized Explosives:

EXPLOSIVE	HEAT Cal/gram	VOLUME OF GAS CC/gram
TNT	924-1040	728-640
80/20	1250	900
RDX	1250	900
TNT/Al 67.8/32.2	2185	267
RDX/Al 67.3/32.7	2340	407
Ammonium Nitrate/Al 59.7/40.3	2181	501

Heretofore the emphasis in military explosives has been on velocity of detonation, or high peak pressures, the effects of which are ordinarily expressed in terms of brisance. As a result of air operations over the European Continent it has been found that, while a high peak pressure is desirable, a sustained impulse over a wide area causes a greater radius of blast damage. This sustained impulse has been increased by the addition of Aluminum to explosives. The effect is to greatly increase the strength without materially affecting the velocity causing a tremendous increase in sustained power. The effect might be compared to taking a 180-pound fullback who can run the hundred in ten seconds and increasing his weight to 210 pounds and decreasing his speed to eleven seconds. It is obvious that while his initial striking force would be slightly reduced, his sustained drive and power would be greatly increased.

The following table will compare peak pressures and impulses of certain explosives using 100 as the value of TNT:

EXPLOSIVE	PEAK PRESSURE	IMPULSE
Torpex*	122-1/2	127-1/2
Minol*	112-1/2	115
Alumatol*	110	115
Composition B	110	110
Ednatol	107-1/2	110
Amatol	95	87-1/2
TNT	100	100

* Indicates aluminized explosives.

Aluminum is frequently added to explosives to increase the incendiary effect caused by the explosion.

9. MISCELLANEOUS INGREDIENTS

A. ANTIMONY SULFIDE - This is a fuel used in most primers. It burns readily and gives a long hot flame when used with Potassium Chlorate.

B. LEAD SULFOCYANATE - Used the same as Antimony Sulfide but to a lesser extent. It has a low ignition temperature (190°C).

C. LEAD CHROMATE - A fuel used to slow down the burning time of delays.

D. SILICON CARBIDE - A gritty material used to increase the sensitivity of friction type Primers.

E. **CARBORUNDUM** - A gritty material used to increase the sensitivity of friction type Primers.

F. **TETRACENE** - An explosive which is more sensitive than Mercury Fulminate and produces a large flame. It is too weak to be used alone but is used to lower the ignition temperature of certain Primers.

G. **MONTAN OR LIGNITE WAX** - This is a coal tar product used by the Germans to desensitize explosives. It is white in color but quite often the explosive in which it is used is dyed for identification purposes.

CHAPTER 3

SECTION I

LOW EXPLOSIVES

While Bomb Disposal Personnel are mainly interested in High Explosives, their clean-up operations will include disposal of quantities of artillery ammunition. Therefore they should be familiar with the various types of low explosives which are currently used as propellants and pyrotechnics. Failure to appreciate the characteristics of Black Powder led to one fatality here at the school.

We shall first consider the qualities desirable in a good propellant and then discuss the two types of propellants with these in mind.

1. Controlled burning:

Any good propellant should produce lots of hot gases which burn at a controlled rate. For example, our guns are designed to withstand a maximum gas pressure in the bore just ahead of the powder chamber. This exerts a higher and more uniform pressure, all the way to the muzzle, than would occur if the peak were reached in the powder chamber. Therefore, it is desirable for the propellant to attain a maximum gas pressure by a gradual and progressive rise in pressure. Control of this pressure lies in the composition of the powder, the form or shape of the individual grains and size or dimensions of any particular form of grain. Granulation determines the area of the burning surface of the grain. This in turn controls the rate of combustion and thru that the pressure. The propellant must be adaptable to this sort of control.

2. Sensitivity:

The propellant should be readily ignitable but safe to manufacture, transport, load, and store.

3. Stability:

The propellant must be able to withstand long storage under all climatic conditions without deterioration.

4. Residue:

The exploded propellant should leave little or no residue. Unexploded powder will corrode gun barrels, create smoke and reduce officiency.

5. Manufacture:

The process should be rapid and the raw materials plentiful.

6. Erosive action:

The burning temperature should be kept at a minimum to prevent erosion of the gun barrel.

7. Flash:

The gases of explosion should be kept as cool as possible to prevent muzzle-flash which will indicate gun positions.

8. Detonation:

The propellant should be incapable of detonation as this would burst the barrel of the gun.

SECTION II

BLACK POWDER

Black Powder or Gunpowder is a very old explosive. The Chinese, Arabs and Hindus all used it in early times. It was probably developed as an outgrowth of the combustible qualities of Potassium Nitrate with a combustible. It was mentioned as early as 660 A.D. and was used as a propelling charge as early as 1313 and in blasting as early as 1627. In fact up to 1880 the word explosive usually implied Black Powder as blasting agent, propellant and bursting charge.

1. Properties of Black Powder:

a. Black Powder is manufactured in shiny black grains.

b. The ingredients are usually Potassium or Sodium Nitrate, Charcoal and Sulphur which are incorporated by wheeling. The charge is pressed into cake and grained to the desired size. The grains are glazed with Graphite to prevent caking and accumulation of static electricity.

The Potassium or Sodium Nitrate (75%) acts as an oxidizing agent while charcoal (15%) and sulphur (10%) are combustibles. Sulphur also lowers the ignition temperature from 340°C to 300°C. It takes fire first and communicates it through the mass. It has collodial qualities and fills the spaces between other components. It also acts as a catalyst and reduces the solid residue. Potassium Nitrate is expensive but only slightly hygroscopic so is used in Fuse Powders while Sodium Nitrate, being cheap but very hygroscopic, is used in blanks and spotting charges.

c. Explosive Properties:

1. Black Powder is extremely sensitive to heat and friction. It will ignite from the slightest spark and burn with explosive violence. It is insensitive to shock but should be treated carefully because in the field it is difficult to disassociate shock and friction. It ignites at about 300°C.

2. Black powder is inferior in strength being only 55% as strong as TNT. It evolves 700 calories and 300 cubic centimeters of gas per gram.

3. It has a burning speed of 1-10 centimeters per second at pressures up to 30,000 pounds per squard inch. The burning speed can be controlled by the following means:

a. To decrease burning speed:

1. Increase compression - This lessens porosity and hampers penetration of hot gases.

2. Increase grain size - This causes degressive burning and slows the wave of ignition from grain to grain.

3. Reduce time of incorporation - This prevents a thorough integration of ingredients.

4. Increase amount of powder incorporated at a time - This serves the same purpose.

5. Increase amount of inert retardant such as asphalt or moisture - This causes the powder to burn irregularly and leaves a large residue.

6. Reduce percentage of oxidizing agent or increase percentage of Sulphur at expense of Charcoal.

7. Use a less efficient oxidizing agent such as Barium Nitrate.

b. To increase burning speed:

1. Increase confinement which increases pressure and heat.

2. Increase temperature - As the ignition temperature is approached the ease of ignition is increased.

3. Increase atmospheric pressure which acts the same as confinement.

4. Decrease the grain size - This tends to make the powder neutral burning and increases the speed of ignition from grain to grain by reducing air space.

d. Because it is very hygroscopic, Black Powder is unstable unless moisture can be completely excluded. It can be destroyed by dumping in water.

2. Comparison with desired qualities:

a. Controlled burning: It is difficult to control the burning speed accurately and hence the range of a shell, propelled by Black Powder, would not be accurate. The gas volume is satisfactory.

b. Sensitivity: Black Powder is too easy to ignite and therefore unsafe.

c. Stability: Its hygroscopicity makes it unsatisfactory from this standpoint.

d. Residue: Black Powder leaves a large amount of solid residue causing corrosion of the bore and much smoke.

e. Manufacture: The process is easy and cheap and raw materials are plentiful.

f. Erosive Action: Black Powder has a fairly high temperature of combustion (2300 to 3800°C) which causes erosion of the bore.

g. Flash: It produces a brilliant flash.

h. Detonation: Black Powder cannot be detonated.

3. Present Uses:

It can be seen that Black Powder was none too efficient as a propellant and has been largely superceded by Smokeless Powders for that purpose. However, it is a very important explosive, being used universally for the following purposes:

a. Primers and igniters in artillery shells.

b. Delay elements in fuzes.

c. Expelling charge for shrapnel.

d. Saluting and blank fire charges.

e. Spotting charges for practice ammunition.

f. Bursting charge for U.S. Army 37 MM Low Explosive shells.

g. Propellant and bursting charge in U.S. Navy 1, 3 and 6 pound shells.

h. Propellant in U.S. Navy 40 MM shells.

i. Burster in U.S. Army incendiary ammunition.

j. Safety fuse (burning rate 1 ft. in 30-40 secs.)

k. Quick match (burning rate 90-120 ft. per sec.)

SECTION III

NITROCELLULOSE EXPLOSIVES

The effect of Nitric Acid on cotton was first observed in 1838. Guncotton was produced in 1848 and Nitroglycerine in 1846. Around 1880 the gelatinizing effect of combining Nitroglycerine and Nitrocellulose was discovered and led to the production of Blasting Gelatin, which is still the one of the strongest explosives known.

Smokeless Powder was first used for blasting but was gradually developed as a propellant to overcome the objectionable features of Black Powder. About 1886 Pyrocotton, Cordite and Ballistite were all developed and gradually replaced Black Powder until at present all nations use some form of gelatinized Nitrocotton as a propellant.

This type of explosive is referred to by various names as follows:

1. Nitrocellulose - Any combination of Cellulose and Nitric Acid.
2. Nitrocotton - Nitrated Cotton.
3. Pyroxylin - Nitrocellulose containing less than 12% Nitrogen.
4. Pyrocotton - Nitrocellulose containing 12-12.75% Nitrogen.
5. Guncotton - Nitrocellulose containing 13% or more Nitrogen.
6. Collodion Cotton - That type of Nitrocotton which dissolves most readily in a solvent. It usually contains 11.2% to 12.2% Nitrogen.

SECTION IV

SMOKELESS POWDERS

Smokeless Powders are forms of Nitrocellulose Explosives used as propellants. They may be divided into two classes, Single and Double base Powders.

1. SINGLE BASE POWDERS

A. Properties:

1. Single base Powders are amber, brown or black in color and are manufactured in flakes, strips, sheets, pellets or perforated, cylindrical grains. The grains usually have one or seven perforations to control the burning speed. The single perforation grain is used in small arms while those with seven perforations are used in larger caliber weapons.

2. The manufacturing process includes the following steps:

a. Purification of the cotton.

b. Nitration with Nitric and Sulphuric Acid.

c. Dehydration by replacing water with Ethyl Alcohol.

d. Formation of a colloid by addition of Ether and more Alcohol which act as solvents. This step includes incorporation of other ingredients which are necessary.

e. Granulation by pressing through steel dies.

f. Solvent recovery, drying, blending and cutting.

g. Glazing with Graphite to prevent accumulation of static electricity and caking. (for small arms only)

3. Ingredients used in the manufacture are:

a. Cotton or wood: Cotton is preferred because wood is less absorbent and requires longer to nitrate; it is harder to purify after manufacture; it requires more acid and is harder to purify of foreign materials. It has certain advantages, however, being purer, less dusty, more easily dried, involves less shrinkage in manufacture and is more easily reduced to pulp.

b. Diphenylamine (DPA): Acts as a stablizer by absorbing nitrous fumes given off by decomposition. About 1% is used.

c. Dibutylpthalate (DBT): This is an inert material used to cool gases and reduce muzzle flash. It is oily and also acts as a waterproofing agent. It replaces volatile solvents and maintains normal buring rate which is increased when volatile matter is lost.

d. Dinitrololuene (DNT): Acts as a coating on small arms powder to control burning rate and reduce hygroscopicity. It displaces volatile matter and, being explosive, compensates for addition of DBT.

e. Trinitrotoluene (TNT): Same as DNT.

f. Triacetin: Acts as a gelatinizing and waterproofing agent.

g. Centralite: Acts as a gelatinizing agent, stabilizer and flash reducer.

h. Vaseline: Stabilizes and cools.

4. Explosive Properties:

a. Single Base Powder is rather insensitive. In fact it is difficult to ignite always requiring a Black Powder Primer and in larger ammunition a Black Powder Igniter. It ignites at 315°C.

In the open Single Base Powder burns very much like Celluloid. Seemingly this explosive is very safe but the fact should not be overlooked that, although it is used as a low explosive, Single Base Powder is an organic compound and will detonate if burned in large quantities or sympathetically from the detonation of other explosives.

b. Single Base Powder is stronger than Black Powder giving off 1000 calories and 900 cubic centimeters of gas per gram compared with 700 calories and 300 cubic centimeters for Black Powder.

c. It has a burning speed of 0.1 to 18 centimeters per second at pressures up to 60,000 pounds per square inch. The burning speed can be controlled by the following means:

1. Variation in the size and shape of the grains including the number of perforations. There are three types of Single Base Powder; (1) Degressive; (2) Progressive; and (3) Neutral burning.

a. If the burning surface decreases as the burning continues, it is a degressive burning powder and the burning rate is decelerated. This type of powder has no perforations.

b. If the burning surface remains constant, it is neutral burning and the burning rate remains constant. This type of powder has one perforation.

c. If the burning surface increases, it is progressive burning and the burning rate is accelerated. This type of powder usually has seven perforations.

2. The web thickness or amount of solid powder between burning surfaces. The thicker the web, the slower the burning.

3. The percentage of volatile, inert materials and moisture present. Volatile and inert materials have a greater effect than water because they use the energy of the powder to burn themselves. The following table compares water and other materials according to the units of energy used:

Water	1
Alcohol	2.5
Graphite	2.5
D.P.A.	4.0

5. Single Base Powder is fundamentally unstable and decomposes in hot, moist storage. It is hygroscopic although not so much as Black Powder. Nitrocellulose in the presence of moisture hydrolizes to free acid which takes the form of Oxides of Nitrogen. These Oxides accelerate the decomposition, building up heat to an ignition temperature and spontaneous combustion results.

B. Comparison with desired qualities:

1. Controlled burning: The burning rate of Single Base Powder can be absolutely controlled to a point where the maximum propelling effect is obtained.

2. Sensitivity: Ignition is difficult and the powder is safe.

3. Stability: The powder is unstable but this can be controlled.

4. Residue: There is little residue or smoke. The powder can be balanced for complete combustion.

5. Manufacture: This is complicated but safe. Raw materials are plentiful.

6. Errosive Action: Single Base Powder errodes the bore but not quite as much as Black Powder. Its combustion temperature is 2700-3500°C.

7. Flash: This is caused by hot gases which take fire when they come into contact with fresh Oxygen at the muzzle. It can be controlled by adding cooling materials to the powder.

8. Single Base Powder can be detonated and has a velocity of 4600 meters per second. However, in actual practice this is rarely a hazard.

C. Present Uses:

It can be seen that Single Base Powder can be manufactured to eliminate the objections to Black Powder. For this reason it is the United States' standard propellant and is widely used by all other nations for the same purpose.

2. DOUBLE BASE POWDERS

This form of Smokeless Powder is known here as Ballistite and in Britain as Cordite.

A. Properties of Double Base Powders:

1. The color is gray-green to black and the forms are the same as for Single Base Powders.

2. They are manufactured the same as Single Base Powders except that Nitroglycerine is used as a solvent instead of Ether and Alcohol. In the manufacture of Cordite, Nitrocellulose and Nitroglycerine are

dissolved in Acetone which then evaporates. The same inert materials are used that as for Single Base Powder except for Cordite which uses Vaseline. The Nitroglycerine content is usually 30-40%.

3. Explosive Properties:

a. Double Base Powders are more sensitive than Single Base Powders igniting at 150°C -160°C. They will also detonate more readily than Single Base Powders.

b. They are stronger than the Single Base Powders producing more gas and exploding at higher temperatures.

c. They have a faster burning rate which can also be controlled (see Single Base Powders).

4. The presence of Nitroglycerine eliminates hygroscopicity and stabilizes the powder. In other words the powder has an active stabilizer and solvent.

B. Comparison with desired qualities:

1. Controlled Burning: Burning can be controlled as with Single Base Powders.

2. Sensitivity: This is greater but not so much so that the powders are unsafe.

3. Stability: Double Base Powders are stable and do not require inert ingredients which reduce strength.

4. Residue: Since there is not so much inert material there is less solid residue and corrosion.

5. Manufacture is much the same. However, it is significant that Germany is now running short of glycerine and is using substitutes.

6. Errosive Action: This is increased because of the higher burning temperature.

7. Flash: This also increases for the same reason. Cooling agents can be added, however.

8. Detonation: Double Base Powders are more easily detonated than Single Base Powders.

C. Present Uses:

All the Warring Nations use Double Base Powders as a Standard Propellant except the United States (Cordite is the Standard British Propellant).

We use Ballistite in Mortars where the confinement is not as great as in the barrel of a gun and a faster burning powder is required.

We also use it in special ammunition, such as rockets, for the same reason. Double Base Powders are more efficient than Single Base and evidently foreign nations feel that this outweighs the objectionable features of errosion and flash.

SECTION V

PYROTECHNICS

Literally the term Pyrotechnic pertains to fireworks. Army nomenclature designates illuminating devices as Pyrotechnics. They include Signals, Flares, and Photoflash Bombs. They are manufactured from the following components:

1. Fuels such as Aluminum, Magnesium, Sulphur, Asphalt, and resinates of Calcium, Strontium, Barium, and Copper.

These materials are the combustibles which burn when supplied with Oxygen. They correspond to the Charcoal and Sulphur in Black Powder.

2. Oxidizing Agents such as Potassium and Ammonium Perchlorate; Barium and Potassium Chlorate; Barium, Potassium, Strontium and Sodium Nitrate and Chromates of Strontium and Barium.

These materials supply the Oxygen for combustion and in some cases act as coloring agents. An increase in the amount of oxidizing agent increases the burning rate and candlepower of the mixture. They correspond to the Nitrates in Black Powder.

3. Coloring Agents such as Barium (green), Strontium (red) and Copper Chloride; resinates of Strontium and Copper and Sodium and Strontium Nitrate. Some of these material also act as oxidizing agents. When this is true the color can be added without affecting the burning rate and candle power.

4. Retardants, Binding and Waterproofing Agents such as Asphalt, Paraffin, Sulphur and resinates of metals.

It can be seen that these materials are essentially forms of Black Powder and should be handled as such.

Flares and signals are not designed to explode but to burn for periods of a few seconds up to several minutes giving off light and heat of intensities up to 800,000 candle power.

Photoflash Bombs on the other hand burn with explosive violence giving out 300,000,000 candle power in .165 seconds. This amounts to an explosion and for that reason they are designated as bombs.

Pyrotechnics are all fundamentally as sensitive as Black Powder to flame and friction. In addition, if the Pyrotechnic contains Magnesium, Magnesium can react in the presence of moisture to form Magensium Oxide, Hydrogen Gas and heat. Hydrogen and Oxygen form an explosive mixture which can ignite spontaneously.

It can be seen that these materials are dangerous and cannot be inerted by removing the fuze. They should never be opened but should be destroyed in place by demolition or dumping in large bodies of water.

Flares can blind or kill by burning and have been known to explode.

Photoflash Bombs are as dangerous to personnel as High Explosive Bombs.

An example of a typical Flare follows:

Green Flare

Barium Nitrate	33.7%
Magnesium	30.3%
Aluminum	15.2%
Sodium Oxalate	18.8%
Castor Oil	1.0%
Linseed Oil	1.0%
	100.0%

SECTION VI

INCENDIARIES

Incendiaries are being widely used in this war. In reality, they are a form of Pyrotechnic but are not designed to explode or to give light but rather to burn for periods up to fifteen (15) minutes giving out intense heat.

The three main incendiaries are:

1. Thermite or Thermit

This incendiary is used by all nations. It consists of Iron Oxide/Aluminum 76/24 and burns with a temperature of 3000°C.

2. Thermate

This is a United States incendiary designed to lower the ignition temperature and increase the burning speed of Thermite. Its composition is:

Thermite			80%
First Fire Charge			20%
Sodium Nitrate	50%)		
Aluminum	45%)		
Sulphur	4%)	75%	
Linseed Oil	1%)		
	100%		
Black Powder		25%	
		100%	

3. Elektron

This is a German trade name for an alloy consisting of 86/14 Aluminum/Magnesium. It is used by all nations as a casing for incendiary Bombs and burns at 1500°C:

Magnesium by itself burns at 4200°C but cannot be used as a casing because it is very reactive and therefore unstable.

There is an endless variety of incendiaries used for various purposes but practically all are based on the combination of Aluminum or Magnesium and Oxidizing agents to control the ignitability, burning time and temperature.

CHAPTER 4

SECTION I

HIGH EXPLOSIVES

High Explosives may be subdivided into two classes according to their sensitivity which in turn governs their use. These classes are:

1. Primary High Explosives

These explosives are extremely sensitive to shock, friction and heat. They will not burn but will always detonate if they are ignited. Their strength and brisance are inferior but are sufficient to detonate secondary high explosives. Because of their sensitivity they are used for this purpose.

2. Secondary High Explosives

These explosives are relatively insensitive to shock, friction and heat. They will usually burn rather than detonate if ignited in small quantities in the open. In fact burning is one of the best methods for destroying them. A small quantity, 50 to 100 pounds, can be spread out thinly over the ground and ignited by means of a train of excelsior saturated with kerosene. Normally the explosive will burn but personnel engaged in this operation, should be prepared for a detonation.

There is a certain temperature at which all explosives will detonate. They may attain this temperature from external heat or from their own burning. For this reason, bombs should not be burned out with oil soaked rags or Thermite unless the same precautions, ordinarily taken for the demolition of a bomb, are observed. No explosives will normally stand the heat of Thermite without at least a partial detonation.

Secondary high explosives are used as boosters and bursting charges.

SECTION II

THE EXPLOSIVE TRAIN

Primary and Secondary High Explosives are combined, for military purposes, into what is known as an explosive train. This may be defined as a series of steps by which a small initial amount of energy is converted into the large amount of energy necessary to insure a high order of detonation for the bursting charge.

Fundamentally an explosive train consists of a primer, detonator, booster and bursting charge. This sequence is often interrupted by a delay but as this does not alter the basic concept we will discuss it later under the subject of individual, national, explosive trains.

In order to explain this principle let us assume that we have a 2000-pound bomb filled with TNT and that our fuze is the firing pin type. Obviously TNT will not detonate from the stab action of a firing pin or it would be unsafe to use in large quantities. So, because our initial source of energy is the friction or percussion effect of the firing pin, we must step up this energy to a point where it will detonate TNT. This is accomplished by means of an explosive train.

The first component, or primer, then must consist of an explosive which will detonate from the stab action of a firing pin with sufficient violence to detonate the second component. Such an explosive is extremely sensitive but not violent enough to insure a high order of detonation for the bursting charge, at least in quantities that would be safe to use.

The second component, or detonator, must readily detonate from the action of the primer and, at the same time, develop sufficient energy to detonate the third component. Here again, a very sensitive explosive is required although not as sensitive as the primer. While such an explosive might detonate the bursting charge, the quantity necessary would make the ammunition unsafe.

For this reason we incorporate a third component called the booster. It is intermediate in sensitivity. It will readily detonate from the action of the detonator, develop a high degree of power to insure a high order of detonation for the bursting charge and at the same time is sufficiently insensitive to be used in fairly large quantities.

The fourth component is the bursting charge itself which is readily detonated by the booster.

This sequence of components is analogous to the ignition of a coal fire. Everyone realizes that it almost impossible to ignite a piece of anthracite coal with a match yet we require a match, or some similar form of heat, to start our fire. Therefore, we use the match to ignite paper. It is possible to ignite coal with paper but not in any quantity. In effect you would get what might be described as a low order deflagration. So we use the paper to ignite wood which will form a bed of coals and give us a roaring fire immediately.

In this procedure you can compare the match with the primer, the paper with the detonator, the wood with the booster, and the coal with the bursting charge.

In each case we start off with a very small quantity of a very sensitive material and gradually increase our quantity and decrease our sensitivity ending with a very large quantity of a very insensitive material.

SECTION III

LOADING EXPLOSIVES

After deciding on the best Military Explosive for the purpose in view, it must be loaded into its container. In most ammunition it is desirable to load the explosive at a maximum density for the following reasons,

1. Density is the controlling factor in velocity of detonation.

2. Other things being equal, the greater the density the more explosive and hence the more power we have in the space provided.

3. If density is low we may have cavities in the charge which may cause:

a. Misfires if the cavities are around the booster or permit the charge to move away from the booster.

b. Low order of detonation if the cavities prevent the propagation of the detonating wave.

c. Premature detonations from set back or set forward if the charge can move within the container.

4. High density decreases sensitivity:

To obtain the maximum density most economically, cast or melt loading is used. By this method, the explosive is melted and poured into the ammunition and allowed to cool. Recently, by using preformed pellets with the melted explosive, we have cut loading time, for the one-ton bomb, from three days to three hours.

An alternative method is press loading. By this method the explosive is powdered and pressed into the container by a ram either in the powder form or with a lubricant, such as Graphite or Stearic Acid, to ease the action of the ram. While it is possible to obtain as high, or higher densities by press loading, the process is a time consumer and would seriously affect production.

A third method is Extrusion, a method by which the explosive is fed into a hopper and extruded into the container by a screw which extends inside of the container. This method is used to prevent hygroscopic explosives from coming into contact with the air.

For special purposes it is sometimes undesirable to have a maximum density so the explosive is poured into its container in powdered or flaked form or pressed lightly.

Examples are:

1. Boosters where greater sensitivity is desired.

2. Land Mines and Grenades where greater sensitivity and a less violent detonation are desirable. The latter prevents disintegration of the casing into too many small fragments.

SECTION IV

REQUIREMENTS OF A GOOD MILITARY HIGH EXPLOSIVE

Before selecting an explosive for use as a booster or bursting charge, the following characteristics of the explosive must be carefully weighed.

1. Velocity of detonation is the most important characteristic. When we stop to consider the fact that a pound of coal has five times the energy of a pound of explosive, it is easy to see that the speed with which energy is released is all important. This is of special importance from a Military standpoint because Military Explosives are detonated in the open for the most part. They must detonate rapidly in order that they may attain a maximum gas pressure before the gases are dissipated in the atmosphere. For example, let us assume that a 2000 pound bomb is detonated by a nose fuze. If the explosive detonates slowly the expanding gases from the nose will start toward the objective before the tail part has detonated. However, if a fast acting explosive is used, more of the explosive will have detonated before the gases begin to expand and a larger amount of energy will be delivered at one time. Therefore, the faster the explosive the more violent its action.

2. Strength is also a very important factor. Granted that an explosive has an adequate velocity, the more energy it liberates the greater will be its power. Strength is of primary importance when an explosive is confined, as in underwater ammunition. Here the water confines the gases and permits a maximum pressure to be reached without dissipation even with slower acting explosives. Incidentally, an explosive is four and one half times more effective when it is confined. It acts like any other force. If an explosive detonates alongside of a building the surrounding air does not supply a resistance equal to that of the building and the greater portion of the explosive force will be dissipated and comparatively little of it will affect the building. In actual practice this tendency is offset by using very large bombs.

3. Sensitivity is of almost equal importance. The explosive must be safe to manufacture, transport, store and load. It must be bore safe in the case of shells and must be safe to jettison in the case of bombs. At the same time it must be readily detonated by the action of a suitable Explosive Train.

4. Stability is always important but it is especially so in this war with fighting taking place all over the globe and under all climatic conditions.

5. Hygroscopicity must be considered because of its effect on Stability, Sensitivity, Velocity and Strength.

6. Melting Point is important considering the desirability of cast loading. The Melting point should be between 80° and 100°C. If it melts lower than 80°C there is a tendency for the explosive to exude under hot storage conditions. If it is higher than 100°C the explosive cannot be melted by hot water. The use of other forms of heat is dangerous particularly as decomposition often takes place at temperatures above 100°C.

7. Reaction with Metals is undesirable but not a controlling factor in the selection of an explosive.

8. Availability of Raw Materials is a prime consideration. The best explosive known cannot be used if its raw materials are not plentiful. For this reason many reserve explosives become first line explosives during wars.

9. Cost of Manufacture is not too important in time of war. However, if other factors were equal, it might be the deciding factor.

In the selection of Primary High Explosives the following factors must be considered:

1. Sensitivity is of prime importance. The explosive must be as sensitive as possible compatible with a decent degree of safety in manufacture, transportation, storage and use.

2. Velocity of Detonation does not need to be as high as for Boosters and Bursting Charges but the explosive must attain maximum velocity of detonation in a very short column since very small amounts of the explosive are used.

3. Strength is not a factor but the explosive must give a long, hot flame on detonation.

4. Stability is even more important than for Secondary High Explosives. A low order of detonation for a Primer or Detonator can cause the entire bomb to become a dud.

5. Hygroscopicity, therefore, is also extremely important in that it affects stability, sensitivity and velocity.

6. Melting Point is not a consideration.

7. Reaction with Metals can be readily avoided.

8. Availability of raw materials is important but to a lesser degree due to the small amount of explosive used.

9. Cost of Manufacture is not a factor in selecting this type of explosive.

SECTION V

A TABLE OF HIGH EXPLOSIVES

GIVING A COMPARISON OF CERTAIN CHARACTERISTICS

In order that the more important characteristics, of the more commonly used explosives, may be discerned at a glance the following table is presented showing the explosives in the order of their sensitivity.

The figures used were obtained from a variety of sources. Information was often conflicting but every effort has been made to use the figures which are most nearly correct.

An attempt has been made to compare the explosives showing their relationship to TNT, the characteristics of which are well known. While there may be some disagreement concerning the actual figures, there can be little or none concerning the relationship of the various explosives to TNT, Tetryl and Mercury Fulminate.

An explanation of the method of conducting the tests, from which the figures are derived, follows the chart.

CHART

Column 5 - Sensitivity to shock - The figures are given in inches. This test is conducted by loading 0.02 grams of the explosive in a cup, placing a brass cover over the explosive and then placing the cup, with the cover up, in an anvil. A plug is placed on top of the cover and a 2 Kg. weight is dropped on the plug. The weight is supported between two guides.

EXPLOSIVE (1)	FORMULA OR PROPORTIONS (2)	COLOR (3)	DENSITY (4)	SENSITIVITY TO SHOCK	
				(DROP TEST) INCHES (5)	(RIFLE BULLET % TIMES AFFECT (6)
Mercury Fulminate	$Hg(ONC)_2$	White - Grayish Yellow	3.55	2	100
Nitroglycerine	$C_3H_5(ONO_2)_3$	Pale Yellow - Liquid	1.60	2 - 3	100
Lead Styphnate	$C_6H(NO_2)_3(O_2Pb)$	Deep Yellow	3.1	2 - 3	100
Lead Azide	$Pb(N_2)_3$	White - Buff	3.8	3 - 4	100
PETN	$C(CH_2ONO_2)_4$	White	1.63	6	100
Cyclonite	$(CH_2)_3N_3(NO_2)_3$	White	1.65	7	100
Tetryl	$C_6H_2(NO_2)_3(NCH_3NO_2)$	Buff - Lemon Yellow	1.57	8	90 - 100
Nitrostarch	40/37.7/20/0.8/1.5, NS/SodNit/BarNit/Oil/Stabilizer	Gray	1.6	8	90
Pentolite	50/50 - PETN/TNT	Dirty White - Buff	1.56 - 1.63	9	92
Torpex	42/40/18, RDX/TNT/AL.	Gray	1.73	9	52 - 100
Hexanitrodiphenylamine	$(C_6H_2)_2NH(NO_2)_6$	Deep Yellow	1.58	9	87
Tetrytol	75/25, Tetryl/TNT	Light Yellow	1.60	10	20 - 35
Edna	$(CH_2)_2(NH)_2(NO_2)_2$	White	1.50	10	80
HBX	21/21/40/18, RDX/NH_4NO_3/TNT/Al	Gray	1.68	10	49
Hexamite	60/24/16, TNT/HND/AL	Greenish Gray	1.72	10	Will Detonate
Minol II	40/40/20, NH_4NO_3/TNT/AL	Gray	1.65	10 - 11	48
Cyclotol (Comp B)	60/40, RDX/TNT	Dirty White - Buff	1.62	11	20
Novit	60/40, TNT/HND	Lemon Yellow	1.5	11.5	Will Detonate
Tritonal	80/20, TNT/AL	Gray	1.7	12	36
Baratol	90/10, TNT/Barium Nitrate	Buff	1.65	12	20
Type 98 Explosive	60/40, Trinitroanisole/HND	Lemon or Greenish Yellow	1.5	12.5	20
Composition C_2	80.1/4/10/4/1/.9, RDX/MNT/DNT/TNT/Colladion Cotton/Dimethyl Formamide	Yellow Brown	1.57	12.5	20
Picric Acid	$C_6H_2OH(NO_2)_3$	Light Cream	1.6	12 - 13	24
Ednatol	60/40, Edna/TNT	Dirty White - Buff	1.62	12 - 13	17 - 21
Tridite Shellite	Picric Acid 60, 70, 80, 90% DNP 40, 30, 20, 10%	Cream Yellow	1.62	12.5 - 14 Shellite - 14	4 - 20
Trimonite	Picric Acid 70, 80, 90% MNN or DNN 30, 20, 10%	Cream Yellow	1.6	13 - 15.5	0 - 10
TNT	$C_6H_2CH_3(NO_2)_3$	Buff - Light Brown	1.55	14	4
Composition C	88/12, RDX/Oil	Brown	1.50	14	0
Amatol 50/50	50/50 Ammonium Nitrate/TNT	Buff - Dark Brown	1.54	14	0
Composition A	91/9, RDX/Beeswax	White - Buff	1.62	14	0
Amatol 80/20	80/20, Ammonium Nitrate/TNT	Buff - Dark Brown	1.38	15	0
Trinitroanisole	$C_6H_2OCH_3(NO_2)_3$	Colorless - White - Buff	1.4	15 - 16	0
EDD	$(CH_2)_2(NH_2)_2(HNO_3)_2$	White	Not Available	15 - 21	0
Black Powder	75/15/10, Potassium Nitrate/Charcoal/Sulphur	Black	Not Available	16	100
Explosive D	$C_6H_2(ONH_4)(NO_2)_3$	Lemon Yellow Orange - Reddish Brown	1.48	18	0 - 10

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	SENSITIVITY TO SHOCK		IGNITION TEMP. DEGREES C	TRAUZL BLOCK TEST (STRENGTH) CUBIC CENTIMETERS	BALLISTIC MORTAR (STRENGTH) % OF TNT	VELOCITY METERS/SECOND	BRISANCE GRAMS OF SAND	MELTING POINT DEGREES C	
	(DROP TEST) INCHES (5)	(RIFLE BULLET) % TIMES AFFECTED (6)	(7)	(8)	(9)	(10)	(11)	(12)	
	2	100	210/145	150	-	4700 - 5400	15.5 - 22.4	Explodes	Prime
	2 - 3	100	180	515 - 600	15.6	8400	60.0	13	Doubl
	2 - 3	100	240/200	120	-	4900 - 5200	9.5 - 21.4	Explodes	Prime Prime
	3 - 4	100	330/245	115	-	4000 - 5000	13.9 - 18	Explodes	Deton
	6	100	210/172 - 175	500 - 560	16.6	8300	61.9	138 - 141	Boost
	7	100	260/197 - 204	525	16.2	8400	61.0	200 - 203.5	Boost
	8	90 - 100	260 164 - 165	375	1[illegible].0 - 12.5	751[illegible]	53.5	128.5 - 130	Boost
	8	90	195	275	9.6	6100	37.7	Explodes	Demol
	9	92	220/174 - 178	345	13.0	7500	53.0	80 - 90	Burst
	9	52 - 100	280/185 - 190	475	1[illegible].0 - 17.0	7300	57.9	88 - 95	Burst
	9	87	250 - 260 237 - 246	315	11.3	7200	45.0	250	Mixtu
	10	20 - 35	179 - 181	350	12.0	7300	50.0	65 - 90	Demol
	10	89	180/169 - 173	354	14.1	7800	51.0	174 - 179	Mixtu
	10	49	200 (Estimated)	465	14.6	6800	[illegible]0	80 - 90	Burst
	10	Will Detonate	200 (Estimated)	330	13.0	6900	[illegible]0	80 - 90	Burst
	10 - 11	48	265 254 - 264	465	14.3	5400 - 5700	40 - 41	80 - 90	Burst
	11	20	270/188 - 194	375	13.5	7600	51.8	85 - 100	Burst
	11.5	Will Detonate	250 (Estimated)	300	10.5	7000	44.0	80 - 90	Burst
	12	36	240 - 280	360	11.8	5500	42.0	80 - 90	Burst
	12	20	240 - 260	280	9.8	5900	36.0	76 - 80	Burst
	12.5	20	237 - 246	310	10.9	7000	44.0	67 - 70	Burst
	12.5	20	265 172 - 177	450	13.5	8000	55.0	67	Burst
	12 - 13	24	320 300 - 304	300	10.6	7200	45.0	120.3 - 122.5	Burst
	12 - 13	17 - 2[illegible]	190 159 - 165	325	11.9	7400	48.0	80 - 90	Burst
	12.5 - 14 Shellite - 14	4 - 2[illegible]	315 300	260 - 290 Shellite - 270	[illegible].0 - 10.0 Shellite - 9.1	6300 - 7000 Shellite - 6600	36.0 - 43.0 Shellite-38.5	80 - 90 Shellite-83	Burst
	13 - 15.5	0 - 10	315 300	210 - 270	4 - 9.5	5000 - 6500	32.0 - 40.5	90 - 105	Burst
	14	4	240 - 280 160	265	10.0	6900	43.0	80.2	Burst
	14	0	285 177 - 180	360	12.5	7400	46.5	200 - 203.5	Demol
	14	0	265 254 - 256	330	10.9	6500	38.0	80 - 65	Burst
	14	0	250	410	13.0	7500	49.6	200 - 203.5	Burst
	15	0	260 254 - 256	360	11.7	5400	32.0	76 (Softens)	Burst
	15 - 16	0	290 - 296 165	300	10.6	6900	43.0	64 - 68.4	Burst
e	15 - 21	0	270	345	1[illegible].4 - 12.8	Not Available	Not Available	185 - 187	Burst
e	16	1[illegible]	300	155	5.5	400	8.5	Decomposes	Delay
	18	[illegible] 30	320 288 - 291	275	9.6	6500	35.0	Decomposes 265	Burst

3

ON TEMP. REES C (7)	TRAUZL BLOCK TEST (STRENGTH) CUBIC CENTIMETERS (8)	BALLISTIC MORTAR (STRENGTH) % OF TNT (9)	VELOCITY METERS/SECOND (10)	BRISANCE GRAMS OF SAND (11)	MELTING POINT DEGREES C (12)	USE (13)
45	150	-	4700 - 5400	15.5 - 22.4	Explodes	Primers & Detonators
	515 - 600	15.6	8400	60.0	13	Double Base Powder - Dynamite
0	120	-	4900 - 5200	9.5 - 21.4	Explodes	Primers - Sensitizer for Primers & Detonators
45	115	-	4000 - 5000	13.9 - 18	Explodes	Detonators & Primers.
2 - 175	500 - 560	16.6	8300	61.9	138 - 141	Booster - Mixtures.
7 - 204	525	16.2	8400	61.0	200 - 203.5	Booster - Mixtures.
4 - 165	375	1[illegible].0 - 12.5	7500	53.5	128.5 - 130	Booster - Mixtures.
	275	9.6	6100	37.7	Explodes	Demolitions.
74 - 178	345	13.0	7500	53.0	80 - 90	Bursting Charge.
85 - 190	475	1[illegible].0 - 17.0	7300	57.9	88 - 95	Bursting Charge.
260 246	315	11.3	7200	45.0	250	Mixtures
181	350	12.0	7300	50.0	65 - 90	Demolitions - Bursting Charge
69 - 173	354	14.1	7800	51.0	174 - 179	Mixtures
(Estimated)	465	14.6	6800	48.0	80 - 90	Bursting Charge.
(Estimated)	330	13.0	6900	48.0	80 - 90	Bursting Charge.
54 - 264	465	14.3	5400 - 5700	40 - 41	80 - 90	Bursting Charge.
88 - 194	375	13.5	7800	51.8	85 - 100	Bursting Charge.
(Estimated)	300	10.5	7000	44.0	80 - 90	Bursting Charge.
280	360	11.8	5500	42.0	80 - 90	Bursting Charge.
280	280	9.8	5900	36.0	76 - 80	Bursting Charge.
246	310	10.9	7000	44.0	67 - 70	Bursting Charge - Boosters.
72 - 177	450	13.5	8000	55.0	67	Bursting Charge - Demolitions
300 - 304	300	10.6	7200	45.0	120.3 - 122.5	Bursting Charge - Booster
159 - 165	325	11.9	7400	48.0	80 - 90	Bursting Charge
300	260 - 290 Shellite - 270	[illegible].0 - 10.0 Shellite - 9.1	6300 - 7000 Shellite - 6600	36.0 - 43.0 Shellite-38.5	80 - 90 Shellite-83	Bursting Charge
300	210 - 270	[illegible].4 - 9.5	5000 - 6500	32.0 - 40.5	90 - 105	Bursting Charge
- 280 180	265	10.0	6900	43.0	80.2	Bursting Charge - Booster
177 - 180	360	12.5	7400	46.5	200 - 203.5	Demolitions
254 - 256	330	10.9	6500	38.0	80 - 85	Bursting Charge
	410	13.0	7500	49.6	200 - 203.5	Bursting Charge
254 - 256	360	11.7	5400	32.0	76 (Softens)	Bursting Charge
296 165	300	10.6	6900	43.0	64 - 68.4	Bursting Charge
	345	1[illegible].4 - 12.8	Not Available	Not Available	185 - 187	Bursting Charge
	155	5.5	400	8.5	Decomposes	Delays
288 - 291	275	9.6	6500	35.0	Decomposes 265	Bursting Charge

By this method the distance, through which it is necessary to drop the weight to secure one detonation in ten drops, is determined in inches and given as the sensitivity of the explosive.

The figures are of value only from a comparative standpoint and will vary with conditions. They are difficult to duplicate. The figures given in column 5 are the concensus of many figures and are calculated to show the sensitvity of the explosives compared with TNT.

Column 6 - Sensitivity to the Impact of a Rifle Bullet.

This test is conducted by firing a .30 caliber Rifle bullet from 30 yards at the explosive which is cast in capped iron pipe of about 1/8" wall thickness. The results are normally expressed as:

1. Number of trials.
2. High Order Detonations.
3. Low Order Detonations.
4. Number of times the explosive burned.
5. Number of passes or times in which the explosive is unaffected.

From a B.D. standpoint, we are interested in the number of times the explosive is affected. This is expressed in a percentage figure in Column 6.

Column 7 - Ignition Temperature - The figures are given in degrees centigrade.

This test is conducted by loading 0.03 grams of explosive in a gilding metal shell. The shell is immersed in a Woods Metal Bath (50/25/12.5/12.5 Bismuth/Lead/Tin/Calcium) and the temperature which will cause flash or explosion after five seconds immersion is determined. The five second interval is allowed to permit the heat to overcome the resistance of the explosive and to thoroughly permeate it, raising the temperature to a flash point.

Since the time and area of exposure affect the flash point the laboratory results are given to the left of the block and the lowest flash temperature reported to the right of the block. 5[illegible].

Column 8 - Trauzl Block Test - The figures are in cubic centimeters.

This test is conducted by wrapping 10 grams of explosive in tin foil and loading in a cylindrical hole, 125 MM by 25 MM, in a cylindrical lead block, 200 MM by 200 MM, and tamping with sand. The explosive is detonated and the volume of expansion caused by the detonation is measured and given in cubic centimeters.

This figure in reality measures the strength of the explosive rather than the brisance. However, if the block is sectioned it can indicate the brisance. If the hole is enlarged only at the bottom it indicates rapid detonation which affected only the part around the explosive.

If the hole is enlarged all along its length it indicates that the explosive reacted slowly, blowing the tamping out of the hole before detonation was completed and thus affected the entire length of the hole.

Column 9 - Ballistic Mortar Test - Figures are percentages using TNT as 10.

The test is conducted by wrapping 10 grams of TNT in tin foil and shooting it in a steel mortar suspended on a pendulum. The deflection of the mortar is measured. Then the TNT can be compared with other explosives by measuring the deflection caused by 10 grams of the explosives in question or measuring the amount of explosive required to give the same deflection as 10 grams of TNT.

The results are given in percentages of TNT using the latter as a base because of its uniformity of action.

Column 10 - Velocity of Detonation - Figures are in meters per second.

This test can be conducted by two methods. The Mettegang Method is the most accurate. It uses a steel cylinder with a smoked surface rotating at 100 meters per second relative to a platinum point. The explosive is loaded into a cartridge and two copper wires are passed through the explosive at a fixed distance apart. Each wire is a closed circuit. The explosive is detonated and as each circuit is broken in turn the platinum makes a mark on the cylinder. Because the cylinder is rotating at a fixed rate of speed and the distance between the wires in the cartridge is known, the velocity of detonation can be calculated.

The second method, or Dautriche Method, involves the comparison of the explosive under test with the velocity of Primacord Detonating Fuse, which detonates at 6200 meters per second.

A measured length of Primacord is laid on a lead plate, and the center point or "C" is marked on the plate. Both ends of the Primacord are inserted in a cartridge of the explosive to be tested. The distance apart in the cartridge is measured and called "AB". The cartridge is detonated and first leg "AC" and then leg "BC" of the Primacord is detonated by the cartridge. The two explosive waves in the Primacord meet at some point "D", which is on the plate between "C" and "B", and leave a V mark on the plate:

Using this information it is possible to compute the speed of the unknown by the formula:

$$\frac{\text{THE RATE OF DETONATION IN THE CORD}}{\text{Distance CD}} \text{ equals } \frac{\text{RATE OF DETONATION OF THE UNKNOWN}}{\text{1/2 AB}}$$

This method is accurate within 5%.

Column 11 - Relative Brisance - The figures are grams of sand which will be curshed by 0.4 grams of the explosive.

The test is conducted by loading 0.4 grams of the explosive into a gilding metal shell. The shell is placed in a bomb containing 200 grams of Ottawa Silica sand which will pass through a twenty mesh screen and be retained by a thirty mesh screen. After firing the number of grams of sand that will be sifted by a shaker through the thirty mesh screen, in three minutes, is measured and given as the brisance of the explosive.

This test can also be used to determine the initiating value and the sensitivity to initiation of explosives. After the brisance of an explosive is determined the number of grams of initiator required to reproduce the figure (i.e. to give a high order of detonation) will be the sensitivity of the explosive to initiation and at the same time the initiating value of the initiator.

Column 12 - Melting Points - The figures are given in degrees centigrate.

Column 13 - Functional uses of the explosive. The principle use is given first.

[illegible]

PRIMARY HIGH EXPLOSIVES
SECTION 1
PRIMARY [illegible]
MERCURY FULMINATE

$Hg(ONC)_2$

Mercury Fulminate is the oldest initiator. It was discovered in 1799 and developed by Nobel in 1864 as an initiator for dynamite. Since that time it has been widely used as a military explosive but at present it is being replaced by other explosives.

1. Properties:

a. Mercury Fulminate is white when pure but in actual use it is usually grayish yellow. It discolors with deterioration.

b. As Mercury Fulminate will not melt it is press-loaded, usually at 3000 pounds per square inch, with a density of 4.5".

c. It is manufactured by dissolving Mercury in Nitric Acid and adding the solution to Ethyl Alcohol.

d. Explosive Properties:

1. Mercury Fulminate is extremely sensitive to shock, friction and heat. Its sensitivity increases with the crystal size due to increase in internal stresses. The Army specifies a maximum dimension of 0.1 4" at which [illegible] test figure is 2".

It detonates at 14[illegible] to 21[illegible] under normal conditions. However, it can be dead pressed at [illegible] pounds per square inch. In this condition hot gases will not penetrate into the interior portion of the explosive and it will burn without detonation although it will detonate from a Mercury Fulminate priming charge.

It can also detonate from the [illegible] by the discharge of static electricity from a person charged with [illegible] volts or less.

The presence of any foreign material, such as sand, will increase its sensitivity to friction.

When manufactured it is not dried but stored under water in linen bags. While not soluble in water or hygroscopic, it is susceptible to moisture and the presence of 1% moisture may prevent detonation from flame or ordinary shock. In this condition it may still be detonated by dry Mercury Fulminate.

2. Mercury Fulminate is inferior in strength being about 52% as strong as TNT. This is not important in an initiator.

3. Mercury Fulminate has a velocity of 4700 to 5400 meters per second and a brisance figure of 15.5 to 2[illegible] depending on the density. This is sufficient for an efficient initiator.

4. Mercury Fulminate is used as a primer and detonator in the explosive train. As a primer it is usually combined with Potassium Chlorate and Antimony Sulfide and quite often with an abrasive. The Chlorate will oxidize the carbon in the compound to Carbon Dioxide increasing the completeness of combustion and the efficiency of the explosive. An 80/20 mixture is considered most efficient.

Specific uses follow:

a. United States:

1. Primers - Friction Type - e.g. Mercury Fulminate/Potassium Chlorate/Antimony Sulfide [illegible]/45/[illegible].

Percussion Type - e.g. Mercury Fulminate/Potassium Chlorate/Antimony Sulfide 3[illegible]/[illegible]5/[illegible].

Mercury Fulminate/Potassium Chlorate [illegible]/10

Mercury Fulminate/Potassium Chlorate/Antimony Sulfide/Ground Glass/Shellac 28/14/21/35/2.

2. Detonators - [illegible] grains used in some Army and Navy detonators.

Picric Acid is used as a lower detonator.

e. Japan:

1. Primers - It is the standard cap primer - e.g. - Mercury Fulminate/Potassium Chlorate/Antimony Sulfide [illegible].6/37.7/31.5

2. Detonators - It has been reported as the Jap Army bomb detonator. This has not been verified by actual analysis and the present detonator is probably lead azide.

f. Italian:

1. Primers - bombs and shells - e.g. - Mercury Fulminate/Potassium Chlorate/Antimony Sulfide/Abrasive 6/44/48/2

2. Primacord - Mercury Fulminate/Wax 7[illegible].4/[illegible].6

3. Mercury Fulminate is unstable. It decomposes after ten months storage at 50°C or three years at 3[illegible]°C, and will not detonate from impact or flame. After seventeen months at [illegible]°C, the brisance decreases

b. Britain:

1. Primers - "A" mixture, Mercury Fulminate/Potassium Chlorate/Antimony Sulfide 45/38.3/16.7

"B" mixture, 11/52.5/36.5

"C" mixture, 32/45/23

Also Mercury Fulminate/Potassium Chlorate 80/20

2. Detonators - Alternate mixture - Mercury Fulminate/Potassium chlorate 80/20

c. Russia:

1. Primers - Shells - Mercury Fulminate/Potassium Chlorate/Antimony Sulfide/Abrasive 11.9/42.5/42.0/3.6

d. Germany:

1. Primers (shells) - e.g. - Mercury Fulminate/Potassium Chlorate/Antimony Sulfide/Ground Glass [illegible]

Also [illegible] Primer for bomb fuzes.

2. Detonators - [illegible] an alternative charge in the same if

from 17.2 to [illegible]. This characteristic makes it unsuitable for use in the tropics.

The fact that moisture will prevent functioning is usually immaterial as it is loaded into a closed container. Primer mixtures containing Potassium Chlorate are hygroscopic.

4. Mercury Fulminate reacts rapidly with Aluminum and Magnesium and slowly with Copper and Copper Alloys. The reaction may take one of several forms viz:

a. May attack Copper causing it to become brittle.

b. Acidity may cause deterioration and corrosion of metals.

c. If free Mercury is present it may form amalgams with metals lowering efficiency of the explosive.

d. Reaction with Copper may form salts more sensitive than Mercury Fulminate itself.

The above reactions are accelerated by the presence of moisture. Mercury Fulminate is loaded into Copper containers and protected from contact with the metal by lacquer.

5. Mercury Fulminate is decomposed by a solution of Sodium Thiosulfate and is soluble in Ammonium Hydroxide, Pyridine and Potassium Cyanide.

6. Mercury Fulminate was used very widely in the past for the following reasons:

a. It is the only explosive known which can act as Primer, Detonator and Booster in one charge.

b. It ignites easily from flame.

c. It detonates readily from impact and friction.

d. It produces a good flame.

It is being almost completely replaced as a detonator and to a large extent as a primer for the following reasons:

a. It is a semi-strategic metal in time of war (especially true of U.S.)

b. It will not detonate cast TNT and Explosive "D" (unless an unsafe quantity is used)

c. It becomes dead pressed at 8500 pounds per square inch, yet it is desirable to load detonators at 10,000 pounds per square inch.

d. It is unstable and affected by moisture.

e. It is not as efficient as Lead Azide.

SECTION II

LEAD AZIDE

PbN_6

Lead Azide is perhaps the most important initiator in general use. It was discovered in 1891, used first in this country in 1913 and produced commercially by 1931.

1. Properties:

a. Lead Azide is a white to buff explosive although it may become grayish brown from exposure to light.

b. Since it does not melt it is pressed into its container generally at 10,000 pounds per square inch and with a density of 3.8. It cannot be dead pressed.

c. Lead Azide is one of the few explosives which contain no Oxygen and the detonation involves no combustion. The reaction is a breakdown into Lead and Nitrogen accompanied by great heat.

Lead Azide is a compound of Lead and Nitrogen manufactured by the reaction of Sodium Azide (Sodium, Ammonia and Nitrous Oxide) and Lead Acetate. Its crystal density is 4.71. Its actual density will depend on the loading pressure.

d. Explosive Properties:

1. Lead Azide is extremely sensitive to shock, friction and heat. It is transported and stored underwater to reduce danger of ignition.

Its sensitivity to impact depends on the crystal size. If the largest dimension of each crystal is over 1 MM it will detonate spontaneously. This is due to an increase in internal stresses. The Army specifies a maximum dimension of 0.1 MM in which size it has a drop test of 3"-4".

It requires a heat of 245° to 350°C to detonate and will always detonate if ignited. It will not burn. From these figures, it can be seen that while Lead Azide is less sensitive than Mercury Fulminate in every respect, in the field, both should be treated with equal care.

2. Lead Azide is inferior in strength (40% of TNT) but this is not a factor in primary explosives.

3. It detonates at a rate of 4000 to 5000 meters per second (4500 at 3.8 density) with a brisance figure of 14 to 1[illegible]. This is low but sufficient for an initiator.

2. Lead Azide is used both as a primer and detonator. As it is not sufficiently sensitive either to stab action or flame to insure 100% operating efficiency it is usually used with other ingredients.

Normally it is used as a friction rather than a percussion primer with the addition of Antimony Sulfide, Potassium Chlorate and an abrasive.

As a detonator it is generally sensitized by the addition of Lead Styphnate to lower the ignition temperature.

Specific uses follow:

a. Primers:

1. United States:

Percussion Type - [illegible] Sulfide/Ground Glass 33.6/14.3/21.5/30.6.

Friction Type - Lead Azide/Potassium Chlorate/Antimony Sulfide/Carborundum 28-1/3/33-1/3/33-1/3/5. This type is also sensitized by Lead Styphnate.

2. Britain:

Friction Type - Lead Azide/Antimony Sulfide/Potassium Chlorate/Abrasive.

b. Relays:

1. United States:

1.54 grains pressed into an aluminum cup at 5000 pounds per square inch and covered with an onion skin.

c. Detonators:

1. United States:

3-15 grains of Lead Azide or Lead Azide sensitized by Lead Styphnate.

2. Britain:

Lead Azide sensitized by Lead Styphnate

3. Russia:

Lead Azide sensitized by Lead Styphnate

4. Germany:

Lead Azide/Lead Styphnate 60/40

Lead Azide/Lead Styphnate 55/45

Lead Azide/Lead Styphnate 14.4/85.6

Lead Azide/Antimony Sulfide/Abrasive 82/7/11 (primer-detonator)

5. Italy:

Lead Azide/Lead Styphnate 55/45

6. Japan:

Lead Azide with Black Powder Relay.

3. Lead Azide is entirely stable under the most adverse storage conditions. It will detonate with as much as 50% moisture present. After hot storage it becomes slightly more sensitive to shock.

4. It reacts only with Copper, to form super-sensitive Copper Azides, in the presence of Carbon Dioxide and water. For this reason it is pressed into aluminum containers.

5. It is decomposed by an Ammonium Acetate solution or Dichlorodiethyl Ether and destroyed by a dilute solution of Nitric or Acetic Acid to which a little Sodium Nitrate has been added.

6. Lead Azide overcomes all the disadvantages of Mercury Fulminate. In addition, although brisance figures show Mercury Fulminate to be slightly superior to Lead Azide, the latter is a much more efficient detonator. The following table will illustrate this point:

Minimum charge in grams of:	Required to detonate 0.5 grams of:			
	[illegible]	Tetryl	Picric Acid	Trinitroanisole
Mercury Fulminate	[illegible]	.24	.22	.37
Lead Azide	.09	.10	.12	.28

This efficiency is due to the fact that Lead Azide attains its maximum velocity of detonation in a shorter column than Mercury Fulminate. This permits a one-third reduction in the amount of the detonator and the use of a longer column of Tetryl.

The disadvantages of Lead Azide are its lack of sensitivity to stab action and flame and the fact that it does not produce a good flame.

The first two objections are easily eliminated but Mercury Fulminate is generally used when flame is desired as with delays.

SECTION III

LEAD TRINITRORESORCINATE

$C_6H(NO_2)_3(O_2Pt)$

This explosive has been widely used commercially and as an iniator for foreign Military Explosives. It has recently been adopted by the United States. It is more frequently called Lead Styphnate.

1. Properties:

a. Lead Styphnate varies in color. It may be pale straw, deep yellow, orange yellow or reddish brown.

b. As it does not melt, it is pressed into its container.

c. It is manufactured from Trinitroresorcinol (Styphnic Acid), Sodium Carbonate and Lead Nitrate. It is the lead salt of Styphnic Acid.

d. Explosive Properties:

1. Lead Styphnate is very slightly less sensitive than Mercury Fulminate (2" to 3" drop test). Its sensitivity is considerably increased after two months' storage at 75°C.

It detonates from temperatures of 200° to 240°C.

2. It has about the same strength as Lead Azide.

3. When properly primed, it detonates at about 5200 meters per second with a brisance of 21.4 compared with 20.3 for Mercury Fulminate under the same conditions. However, when ignited by flame it has a brisance of 9.5 compared with 17.6 for Mercury Fulminate.

Since our detonators usually detonate from ignition, it can be seen that Lead Styphnate is not sufficiently powerful to be used as a detonator by itself. It cannot detonate TNT, Tetryl, PETN or RDX.

2. Lead Styphnate is used in Primers either as the main explosive or as a sensitizer. It is used in detonators to lower the ignition

temperature of Lead Azide. As a Primer it gives a very good flame.

Specific uses follow:

a. United States:

1. Primers - Friction type - Lead Azide composition sensitized by Lead Styphnate.

2. Detonators - Lead Azide sensitized by Lead Styphnate.

b. Britain:

1. Detonators - Lead Azide sensitized by Lead Styphnate.

c. Russia:

1. Detonators - Lead Styphnate over Lead Azide. The explosives are in two layers rather than mixed.

d. Italy:

1. Detonators - Lead Azide/Lead Styphnate 55/45

e. Germany:

1. Primers - The standard electric fuze primer consists of Lead Styphnate/Guncotton 94/6 formed into a paste with Amyl Acetate solvent and beaded on to the ignition bridge.

Examples of other primers - Lead Styphnate/Tetrazine/Antimony Sulfide/Calcium Silicide/Barium Nitrate 37.5/4.2/7.4/12.4/38.5.

Lead Styphnate/Barium Nitrate/Calcium Silicide 49.1/35.5/15.4.

Lead Styphnate/Nitrocellulose 88.7/11.3.

Lead Styphnate/Oxidizing Agent/Antimony Sulfide/Abrasive.

Lead Styphnate/Barium Nitrate/52.1/47.9.

2. Detonators - Lead Azide/Lead Styphnate 60/40 or 55/45 are the standard German detonators.

3. Lead Styphnate is entirely stable in storage.

4. It has no reaction with metals.

5. It is soluble in Acetone.

6. As a substitute for Mercury Fulminate in Primer Compositions, Lead Styphnate offers: sensitivity, stability, a good flame and it is made from non-strategic raw materials. It is worthless as a detonator except as a sensitizing agent.

CHAPTER 6

AROMATIC NITRO COMPOUNDS

SECTION I

TRINITROTOLUENE BASED EXPLOSIVES

1. TRINITROTOLUENE

$C_6H_2CH_3(NO_2)_3$

This explosive, generally called TNT, was used industrially as early as 1891. It was adopted as a shell filler by Germany in 1902 and the U.S. in 1904 replacing Picric Acid which gradually assumed the status of a reserve explosive.

TNT is also known by the following names:

United States - Triton, Trilite, Tritol, Trinol
Britain - Trotyl
Italy - Tritolo
Germany - Sprengmunition 02, Fulpulver 02
Japan - Type 92 explosive
France - Tolite

A. Properties

1. TNT varies in color, from light straw or buff to brownish, depending on the impurities present or the length of exposure to light. In texture it resembles brown sugar.

2. In form it may be granular, pressed or cast depending on the purpose for which it is used. Its melting point of 80.6 permits cast loading.

3. It is manufactured from Toluene and Nitric Acid in a two or three step direct nitration process. Its cast density is 1.55.

4. Explosive properties:

a. TNT is relatively insensitive to shock, friction and heat. It is considered to have a drop test of 14" and it will detonate from bullet impact about 4% of the time. It starts to decompose at 150°C. This becomes rapid at 180°C and the explosive flashes at 240°-280°C.

Like all explosives the sensitivity varies with the density. Granular TNT requires one gram of Mercury Fulminate for detonation, pressed requires two grams and cast requires a Tetryl Booster, or its equivalent. On a drop test basis this would be 11", 12" and 14" for the granular, pressed and cast respectively.

b. TNT is comparatively inferior in strength being equivalent to 45% or 50% dynamite and is 65.5% as strong as Blasting Gelatin. This is caused by an Oxygen deficiency and is evidenced by a thick cloud of black smoke on detonation (pure Carbon residue due to a lack of complete combustion). It expands to 10,000 times its original volume.

c. TNT is fairly brisant detonating at 6900 meters per second with a brisance figure of 43.

B. TNT is used by all nations as a bursting charge in all types of ammunition and in many cases as a booster. At present its use by the Axis, expecially Japan, is drastically curtailed due to a shortage of Toluene.

Specific uses follow:

1. United States - In the cast form it is our standard bursting charge in all types of ammunition except armor piercing.

In the granular form it is used as a filler for Land Mines and the Fragmentation Hand Grenade. It has replaced EC Blank in the Grenade, producing fragments which are effective for a radius of 10 yds. against 2.5 yds. for EC Blank.

Granular TNT is also used by the Navy as an auxiliary [illegible].

2. Britain - TNT is a standard filler for General Purpose, Medium capacity, Semi-Armor Piercing, and Anti-submarine Bombs. It is also used in Land Mines, Fragmentation Bombs, Rockets, Surface Torpedoes, and Shells of all types.

In its pressed form it is used as a booster.

3. Italy - In the cast form it is a filler in all types of ammunition. In its pressed form it is used as a booster for bombs and as a Demolition Charge.

In the granular form it is a filler for Grenades and Land Mines.

4. Germany - Filler #1 FPo2 - TNT pressed in cardboard or metal containers - used in Shells, Depth Charges, Land Mines and Demolitions.

Filler #4 FPc2 - TNT loose in paper containers - used in Grenades of all types.

Filler #7 FPc2 - TNT pressed - Shell filler

Filler #8 FPc2 - TNT Cast - Shell filler

Filler #14 FPc2 - TNT Cast - filler for General Purpose, Semi-Armor Piercing, Armor Piercing, and Anti-Personnel Bombs.

In the pressed form it is also used as an auxiliary booster in all High Explosiv. bombs over 50 kg. and as a Burster in Chemical Ammunition.

5. Japan - Pressed and Cast as a filler in all types of ammunition except bombs and only to a limited extent. This includes Shells, Grenades, Land Mines, and Demolition Charges.

C. TNT is non-hygroscopic and is considered stable. However, it can exude. Exudation is caused by the following:

1. The presence of impurities in the TNT, from manufacturing,

such as DNT, TNB, and TNX. These lower the melting point below 80.2 and cause exudation at elevated temperatures.

2. The use of Alcohol for cleaning threads causes a reaction which produces Ethyl Nitrate Gas.

3. The presence of impurities introduced by Ammonium Nitrate (Amatols).

The exudate is a yellow oily or black, tarry, acidic material which will exude through the fuze pockets or base plates. Exudation takes place under pressure if Ethyl Nitrate gas is present. If moist Ammonium Nitrate has corroded the casing the exudate may carry red material caused by the reaction of Alcohol and TNT in the presence of iron. The acidic oil may also cause this corrosion.

The exudate is not as sensitive as TNT but being on the outside of the bomb it may be exposed to shocks that no explosive material can withstand. In addition it is a dangerous fire hazard and may be corrosive to the booster holder.

More important, however, is the fact that exudation will create cavities in the filler which may result in misfires or premature detonations.

The United States attempts to eliminate exudations by using Grade I TNT (melting point 80.2°C or above) for loading and Acetone, in place of Alcohol, for cleaning. Grade I TNT is used for all cast explosives and mixtures but Grade II (melting point 76°C) can be used for pressed charges and 80/20 Amatol in which the Ammonium Nitrate absorbs the exudate and low density permits expansion. In addition the inside of the ammunition is coated with acid proof paint.

If exudation is suspected it can be verified by placing one or two drops of exudate in a clear glass tube and adding a concentrated solution of lye (Caustic Soda), Drano, liquid soap, soap flakes, yellow soap, Sodium Carbonate, or washing powder. A light to deep red color will develop if TNT or TNT exuate is present.

If the test shows positive the exudate should be removed with Acetone before working with the ammunition.

Exposure to light will cause decomposition which will lower the melting point to 73.5°C, increase the sensitivity, discolor the TNT to brown and cause exudation.

D. TNT does not corrode metals as such but will react with Alkalies such as Sodium or Potassium Hydroxide to produce sensitive salts which ignite at 80°C and can explode spontaneously.

It will react with Ammonia (see Amatols) to produce a highly inflamable material which ignites at 67°C.

With dilute Nitric Acid and lead or iron, TNT can produce the French compound (composition unknown) which ignites on contact with Nitric Acid vapor at 100°C.

E. TNT is soluble in Ether, Alcohol, and Acetone.

F. The use of Tolune as an explosive represents a compromise in utilizing the Aromatic Hydrocarbons. Benzene which produces TNB, a more powerful explosive, is difficult to nitrate and Napthalene, which is easy to nitrate, produces TNN an inferior explosive. The advantages of TNT are;

1. It is easy to nitrate.
2. It has a low melting point for cast loading.
3. It is insensitive to shock and easy to detonate.
4. It is normally stable.

5. It is a fairly powerful explosive.

Its disadvantages are:

1. For most Nations it tends to run short in time of war.

2. It is inferior to most of the new explosives in strength and brisance.

3. It is toxic.

It is highly probable that, in future wars, TNT will assume the position of a reserve explosive or a desensitizer for more powerful explosives.

2. TRINITROLUENE - WAR MIXTURES.

For certain purposes it is necessary to desensitize TNT. This is quite often accomplished by the addition of wax.

A. Properties:

1. Color - Same as TNT

2. Form - Usually cast loaded (melting point 83°C)

3. Manufacture - TNT and varying percentages of wax. (Germany uses Montan or Lignite Wax).

4. Explosive Properties:

a. The sensitivity varies with the percentage of wax always being lower than TNT itself.

b. The strength is decreased in proportion to the amount of wax which robs the explosive of Oxygen when it burns.

c. The velocity and brisance are likewise reduced as wax is inert and does not enter into the detonation.

B. The United States has considered TNT with 5% Beeswax for Armor Piercing Bombs as a substitute for Explosive D. It is reported that it gives better fragmentation and incendiary effect but has not been adopted to date. Britain has used TNT/Beeswax 93/7 (Yellow to amber in color) in Semi-Armor Piercing Bombs.

The chief use, however, has been by Germany in Armor-Piercing Ammunition as follows:

Filler #10 - FP02 plus FP 5 plus FP 10 - Pressed - Shells

Filler #11 - FP02 plus FP10 plus FP15 plus FP20 - Pressed - Shells

Filler #12 - FP02 plus FP 5 plus FP10 - Shells

Filler #27 - FP02 plus FP10 - Pressed - Shells - SAP Bombs

Filler #29 FP 10)
FP 02)
FP 10 plus Potassium Chlorate 70/30) Shells
FP 10 plus Potassium Chlorate 50/50)
Filler #30 - FP02 plus FP6 - Pressed - Shells

Filler #101- FP15 A.P. Bombs

In these German designations, FP 02 indicates TNT while FP5 etc., indicates TNT plus that percentage of wax. Evidently the booster surround is pure TNT with the filler made up in segments. The higher wax content explosives would be in the nose where the shock of impact is more intense. In Filler #29, the Potassium Chlorate is probably added to increase the Oxygen content. As it would increase the sensitivity, the filling is probably used in regular shells, as an extender for TNT, rather than in A.P. shells.

C. Stability - Same as TNT.

D. Reaction with metals - Same as TNT.

E. Solubility - Same as TNT.

F. Aside from the decreased sensitivity, this type of explosive is not attractive as its explosive characteristics are inferior. It is toxic.

3. AMATOL

Amatol was developed during the last war as an extender for TNT and is still used for this purpose. It is called <u>Fulpulver</u> by th

Germans; Amatolo by the Italians; and Shotoyaku by the Japanese.

A. Properties of Amatol:

1. Color: Amatol is naturally white to straw yellow in color but due to the presence of impurities or exposure to light and moisture, it darkens until it attains a dark brown color. It can be distinguished by its grainy, brown sugar appearance.

2. Form: It is usually cast but if the Ammonium Nitrate content is over 60% it will be pressed.

3. Manufacture: Amatol is a mechanical mixture of TNT and Ammonium Nitrate usually used in the proportions of 40/60, 50/50, 60/40 and 80/20. The first figure represents the Ammonium Nitrate content. The actual manufacture is accomplished by pouring Ammonium Nitrate into melted TNT and then pouring the mixture into the ammunition. 80/20 is too stiff to pour so it must be extruded. It is manufactured from Grade II TNT (M.P.76°C). The desired loading densities are:

40/60. . . . . 1.54
50/50. . . . . 1.54
60/40. . . . . 1.54
80/20. . . . . 1.38

4. Explosive Properties:

(a) The sensitivity of Amatol is the same as or slightly less than that of TNT. 80/20 requires a drop test of 15" while 40/60, 50/50 and 60/40 require a drop of 14" compared with 14" for TNT. The Amatols will not ordinarily detonate from the impact of a .30 cal. rifle bullet at 90'. 80/20 has a spontaneous detonation temperature of 254°-280°C with 254°-265° for 50/50. Figures are not available for 60/40 and 40/60.

(b) The strength of Amatol increases with the addition of Ammonium Nitrate due to the fact that Ammonium Nitrate supplies oxygen for a more complete combustion. The 80/20 mixture is best from this standpoint. The strengths compared with TNT are:

80/20 . . . 117% TNT   50/50 . . . 109% TNT

60/40 . . . 110% TNT   40/60 . . . 108% TNT

(c) Due to the low velocity of Ammonium Nitrate the velocity and brisance decrease with the increase in the proportion of Ammonium Nitrate in the mixture. A comparison with TNT follows:

EXPLOSIVE	VELOCITY Meters/Second	BRISANCE
TNT	6900	43
40/60	6600	39
50/50	6500	38
60/40	6200	34
80/20	5400	32

The decrease in velocity is more pronounced when the TNT content is less than 40% due to lowered density as well as to the increase in Ammonium Nitrate.

B. Amatol is universally used, by all nations in all types of ammunition, as a substitute for TNT. Generally speaking the lower Ammonium Nitrate content Amatols are used in smaller ammunition. This is due to the fact that a certain minimum amount of TNT is required to sensitize Ammonium Nitrate. In larger ammunition the Ammonium Nitrate content can be increased leaving the TNT content constant and at the same time having a high order of detonation. Specific uses follow:

1. United States: 50/50 and 80/20 in Light Case, General Purpose and Semi Armor Piercing Bombs. 50/50, 60/40 and 80/20 in Shells.

2. Britain: 60/40 in General Purpose, Medium Capacity, High

Capacity and Anti-Personnel Bombs. Also in Depth charges, Rockets, Grenades, Land and Naval Mines. 80/20, 70/30, 60/40 or 50/50 in Shells of all types.

3. Germany: Filler #13 - 40/60 - General Purpose, Semi Armor Piercing and Anti-Personnel Bombs and Shells.

Filler #13(a) - 50/50 - General Purpose Bombs, Land Mines and Shells.

Filler #88 - 60/40 - Radio Controlled Bombs, Shells and Grenades.

Filler #? - 30/70 Anti-Personnel Bombs

Filler #? - 5/95 Use not known

German case markings, indicating Amatol, are pink with a blue diagonal stripe.

4. Italy: The Italians are reported as using 80/20, 70/30 and 60/40 in all types of ammunition.

5. Japan: Due to a shortage of TNT, Japan uses Amatol very little, It has been reported in Naval Mines.

C. Due to the hygroscopicity of Ammonium Nitrate, Amatol is very unstable in storage unless it is possible to exclude moisture completely. 80/20 will gain 61.1% moisture in two days at 30°C and 90% relative humidity. This will not only lower the sensitivity and velocity to a point of low order detonation or failure, but may cause hydrolysis with the formation of Ammonia. The ammonia will react with TNT causing the exudation of a brown, oily material which will ignite at 67°C. If this reaction has taken place it can be detected by a brown discoloration of the explosive and the smell of Ammonia. Steam should not be applied to the filling under these conditions but the bomb should be washed out with cold water instead.

Cast Amatols exude the same as TNT.

D. Ammonium Nitrate reacts with iron in the presence of moisture to produce Ammonia. Our ammunition is coated with acid proof paint to prevent this and protect the casing from corrosion. In the presence of moisture, Ammonium Nitrate will also react with Copper and Copper alloys to cause a dangerous, blue, crystalline exudation of such salts as Coppertetraminenitrate. To prevent moisture from entering our ammunition, when Amatol is used, we seal the ammunition with a TNT booster surround.

E. Amatol is partially soluble in water and very soluble in Acetone.

F. It can be readily seen that Amatol is not a particularly efficient Military Explosive and therefore is used only as a substitute. It is a stronger explosive than TNT and would be more efficient than TNT if confined as in a cratering charge. When shot in the open, its increased strength does not compensate for its reduced velocity, therefore it is inferior as far as power is concerned. The following figures will serve as an index of its efficiency:

Peak pressure.	95% of TNT
Impulse.	47% of TNT
Shaped charge efficiency.	54% of TNT
Water shock.	94% of TNT

4. AMMONALS

Ammonal was an old World War I explosive which was not regarded very highly due to a failure to realize the effectiveness of Aluminized Explosives and the cost and unavailability of Aluminum. With certain modifications it is assuming increasing importance in this war and is used under the following names:

Ammonal, Alumatol, Burrowite, Minol and Toluol Ammonal (Italian)

A. Properties of Ammonals:

1. Ammonals are usually gray due to the presence of Aluminum in the mixture.

2. They may be cast or pressed depending on the TNT content. Usually mixtures containing less than 40% of TNT will be pressed.

3. The manufacture is accomplished by mixing Aluminum and Ammonium Nitrate and pouring the mixture into liquid TNT. If the mixture cannot be cast it is simply mixed mechanically for press loading.

The following mixtures have been and are being used:

NAME	% TNT	% NH_4NO_3	% AL	OTHER MATERIALS
Ammonal	67	22	11	
Ammonal	12	72	16	
Ammonal	25	50	22	3% Charcoal
Ammonal	30	46	22	2% Brown Coal
Ammonal B(1)		93-95.5	2.5-3.5	2-3% Charcoal
Italian Ammonal (1)		84.5	5.5	(1.5% Potassium (Nitrate (0.5% Barium Nitrate (8% Black Powder
Italian Toluol Ammonal	30	47	20	3% Carbon
Italian Nitramite (1) (2)		71-72	22	6-7% Pitch
British Demolition Ammonal	15	65	17	3% Charcoal
British Demolition Ammonal	15	65	10	10% Charcoal
Nobel's 704	15	69	16	
German Ammonal (1) (2)	.3	91.3	1.7	6.7% Pitch

German Ammonal	30	54	16	
German #19 Filler	55	35	10	
German #110 Filler (1) (3)		90	2.5	(5% Napthalene (2.5% Woodmeal
German #13-113 Filler	20	70	10	
Alumatol	20	77	3	
Burrowite	74	16	10	
Minol	40	35	25	
Minol I	48	42	10	
Minol II (4)	40	40	20	
Minol III	42	38	20	
Baronal (5)	35	—	15	50% Barium Nitrate

(1) Requires a secondary H.E. Primer to detonate.

(2) Chocolate colored, odor of tar.

(3) Light gray color, odor of mothballs.

(4) Most popular at present in Britain.

(5) Experimental-designed to eliminate Ammonium Nitrate.

The loading density of the Ammonals is increased by the addition of Aluminum. The cast explosives run about 1.6 to 1.65.

4. Explosive Properties:

a. Due to the addition of Aluminum, Ammonals are more sensitive than Amatols or TNT. Minol II has a drop test figure of about 10-11" vs 14" for TNT. It will detonate 48% of the time from a .50 cal. bullet at 90'. Its flash point is the same as 50/50 Amatol (254-265°C).

b. The addition of Aluminum raises the heat of detonation to around 4000°C increasing the strength to an average of 1[illegible]% of TNT for Ammonals and 143% for Minol II, [illegible]

[illegible]

c. The addition of aluminum decreases velocity but the greatly increased strength gives a greater brisance than that of Amatol. The velocity of Minol II is 5400-5700 metres per second and the brisance figure about 40 to 41. The British claim their demolition explosive has a velocity of 3300 metres per second which would give it a brisance figure of about 20.

B. Ammonals are now being used in three types of ammunition:

a. Underwater (Mines, Torpedoes and Depth Charges) where the confinement of water offsets the loss of velocity of detonation.

b. Blockbusters in which a sustained and powerful impulse is more destructive than a high peak pressure.

c. Concrete Fragmentation Bombs where the impulse will impart a satisfactory fragment velocity but will not pulverize the concrete. Specifically, Ammonal has been reported as being used in the following ammunition.

1. United States: Ammonal - In shells for testing purposes due to the brilliant flash produced.

2. Britain: Minol II - Sea Mines, Depth Charges, Anti-submarine and H.C. Bombs.

Ammonal - Demolition and Cratering Charges.

Nobel's 704 - Grenades.

3. Germany: Filler #19 - H.E. Shells

Filler #110 - Concrete Anti-personnel Bombs

Filler #13-113 - G.P. Bombs

4. Italy: Reported as being used in all types of ammunition.

C. The Ammonals, being essentially Amatol and Aluminum, have the same type of reaction in the presence of moisture as Amatol. This reaction is accelerated by the presence of Aluminum and five times the amount of Ammonia is produced. In addition, the reaction of Aluminum and moisture produces Hydrogen Gas and Nitrogen. A combination of Hydrogen and Oxygen is highly inflamable and explosive in nature. Therefore, heat should not be applied to Ammonal fillings if the smell of Ammonia is evident or if a brown discoloration is noticed. The filling should be washed out with cold water.

D. The Ammonals have the same type of reaction with metal as the Amatols.

E. They are soluble in water and very soluble in Acetone.

F. The Ammonals (Minol) have become very popular in this war, particularly with the British, due to the fact that the addition of Aluminum greatly increases the power of the explosive. The loss in velocity is more than offset by the increase in gas volume. Giving TNT a value of 100, Minol II has the following properties:

EXPLOSIVE	PEAK PRESSURE	IMPULSE	WATERSHOCK
TNT	100	100	100
Minol II	112	115	133

It can be seen that Minol is especially effective under water where the water acts as a confining medium.

The chief drawback to the use of Ammonals is in the manufacture and loading:

1. It is difficult to secure uniform loading density.

2. If density is over 1.2 it is difficult to insure high order detonations yet at 1.2 or lower premature detonations from impact might occur.

3. It is difficult to keep the explosive dry yet, if moisture enters the ammunition, the reactions described above are probable.

4. There is danger from fires due to the affinity of aluminum for Oxygen.

5. All these difficulties may cut the production rate in half.

5. TRITONAL

This explosive is also called UWE (Underwater Explosive).

A. Properties:

1. This is a gray explosive.

2. It is cast at a density of 1.70 having a melting point of 80-90°C.

3. It is manufactured from 80/20 TNT and Aluminum.

4. Explosive Properties:

a. It has a drop test of 12" and will detonate from the impact of a bullet 36% of the time. It detonates from temperatures of 240-280°C.

b. It is about 18% stronger than TNT.

c. It detonates at 5500 meters per second and has a brisance figure of 42.

B. Tritonal has been used by Germany and Japan for some time in shells mainly to increase the incendiary effect of the explosion. We tried it in Armor-Piercing Ammunition in place of Explosive D, for the same reason, but found that it was too sensitive.

In loading 4000 pound High Capacity Bombs, for the British, with Minol II we ran into production difficulties (see Ammonols) and substituted Tritonal. It met with huge success and is now being considered as an under-water explosive. Specific uses follow:

1. Britain: Bursting charge 4000 pound H.C. Bombs.

2. Germany: Filler #15 - FP02 plus 10% Al - TNT/Al 90/10 - Bursting charge in Shells.

3. Japan: TNT/Al 66/34 - Bursting charge in Shells.

C. Stability - Same as TNT.

D. Reaction with metals - Same as TNT.

E. It is soluble in Acetone.

F. There have been extravagant claims made for this explosive, e.g. it is 80% stronger than TNT; it is equal to Minol II.

Navy tests compare it with Minol II as follows:

EXPLOSIVE	ENERGY OF AIR BLAST	ENERGY OF WATER SHOCK
Minol II	133	138
Tritonal	119	113

It is toxic.

6. BARATOL

This is a British Explosive combining TNT with Barium Nitrate as an Oxidizing Agent.

A. Properties:

1. The color is the same as TNT.

2. It is cast loaded at a density of [illegible] having a melting point of 80-90°C.

3. It is manufactured from [illegible] TNT/Barium Nitrate

4. Explosive Properties (British [illegible]):

a. Its sensitivity is about the same as Picric Acid (Fr test of 12.2") and can be expected to detonate from bullet impact [illegible] of the time.

b. It is very slightly inferior to TNT in strength.

c. It detonates at 5200 meters per second and has a brisance figure of about 36.

B. Baratol is used by the British in Anti-tank Mines, Grenades and Anti-submarine Bombs.

C. The stability is the same as TNT.

D. The reaction with metals is the same as TNT.

E. It is soluble in Acetone.

F. The British claim that Barium Nitrate acts as an extender [illegible] oxidizing agent which does not react with metals and is non-hygroscopic. Also the increased density of the filling results in better propagation of the detonating wave.

They admit that it is not as good an explosive as Amatol but add that, volume for volume, there is little difference.

From this it would seem that Baratol is of value only as non-hygroscopic, non-corrosive extender for TNT. There is little point in substituting a straight oxidizing agent for a combination explosive and oxidizing agent, such as Ammonium Nitrate, as the increased Oxygen does not compensate for the loss of the explosive power of Ammonium Nitrate.

7. MISCELLANEOUS TRINITROTOLUENE EXPLOSIVES

A. German Filler #56 - Donarit.

This is a yellowish, plastic Grenade filler manufactured from Ammonium Nitrate/TNT/Nitroglycerine/Collodion Cotton/Vegetable Meal 67-80/12-25/3.8/.2/4.

Essentially it is 80/20 Amatol formed into a plastic by use of Nitroglycerine and Collodion Cotton. It has about the same explosive characteristics as 80/20 Amatol but is more sensitive.

The Germans indicate Donarit filled Grenades by using green cases with a vertical red stripe.

B. Plumbatol - This is a buff explosive manufactured from 60/40 Lead Nitrate and TNT. It has not been used except experimentally and has little to recommend it, being inferior in every respect to Amatol 60/40. Its only advantage is that it is non-hygroscopid.

C. The Germans have used combinations of TNT and Dinitroaniline in Grenades. DNA is a very feeble explosive and the charge is probably used to prevent the formation of excessively small fragments.

It is a yellow, pressed explosive being very insensitive and of inferior power.

SECTION II

BENZENE BASED EXPLOSIVES

Six pounds of Benzene are produced for every pound of Toluene from coal coking and about three pounds to one from Petroleum Cracking. The Nitrobenzenes are more powerful explosives than the Nitrotoluenes and Nitrophenols but the big drawbacks to their use, as such, are the difficulty of nitration and the consequent low yields.

While the Nitrobenzenes are used, as such, to some extent their main use is as an intermediate with Chlorine in the manufacture of other explosives.

Chlorine is a cheap, plentiful material produced in the manufacture of Caustic Soda. It reacts readily with Benzene to produce Chlorobenzene. This in turn is easily nitrated to Dinitrochlorobenzene. In this form the Chlorine is very active and is readily replaced by other groups such as the Hydroxyl and Amine groups. For example DNCB yields Dinitrophenol by hydrolysis, it reacts with Aniline to form Tetranitrodiphenylamine and with Methylamine to form Dinitromethylaniline. These materials are further nitrated to form Picric Acid, [illegible] and Tetryl.

SECTION III

DINITROCHLOROBENZENE [illegible] AND DERIVATIVES

1. TRINITROPHENYLMETHYLNITRAMINE

$C_6H_2(NO_2)_3(NCH_3NO_2)$

Until the development of the so-called super-explosives, for use in this war, this was the most powerful Military Explosive in general use. It is commonly called Tetryl in this country and C.E. (Composition Exploding) in Britain. It is also known as Tetralite or Pyronite. It was discovered in 1877.

A. Properties:

1. Tetryl is light buff-to-lemon yellow in color.

2. It is pressed into its container at a density of 1.57 as it will start to decompose at 100°C well below the melting point of 129.5° to 130°C.

3. It may be manufactured by nitrating Benzene, treating with iron filings and Hydrochloric Acid to form Aniline, using Methyl Alcohol to form Dimethylaniline and then nitrating to Tetryl. A cheaper method is to manufacture Methylamine from Methyl Alcohol and Ammonia, treat with Dinitrochlorobenzene to form Dinitromethylaniline and then nitrate to Tetryl.

In press loading a [illegible] is necessary [illegible] ram. Graphite is used in this country which gives our Tetryl a gray color.

Stearic Acid has been tried for this purpose. It [illegible] binding agent. It was found, however, that at Tropical temperatures it melts and coats the crystals to such an extent that misfires result.

4. Explosive Properties:

(a) Tetryl is intermediate in sensitivity. While it is safe enough in small quantities such as a booster, it will detonate from the impact of a bullet 90-100% of the time so it cannot be used as a bursting charge in large ammunition. It has a drop test of 8" compared with 14" for TNT. It detonates from temperatures of 164 to [illegible].

(b) Tetryl is 20-25% stronger than TNT.

(c) It detonates at 7500 meters per second and has a [illegible] of 53.5.

B. Tetryl is an almost perfect booster. It detonates readily from the Primary Explosives (.15 grams of Mercury Fulminate will detonate it) and develops sufficient energy to insure a high order of detonation for any of the bursting charges. Specific uses follow:

1. United States - Standard Booster.
Bursting charge in [illegible] and 57 MM shells.
2. Britain - Standard Booster.
Burster in Chemical Ammunition.
3. Germany - Sub-booster in some ammunition.
Bursting charge in land mines
4. Japan - Standard sub-booster
Bursting charge in 25 MM shells
5. Russia - Booster

C. Tetryl is entirely stable but its stability may be decreased from contact with Picric Acid.

D. It may be slightly corrosive to steel.

E. It is soluble in Acetone, can be hydrolized by boiling in an aqueous solution of Sodium Carbonate and can be destroyed by a solution of Sodium Sulfite.

F. Tetryl is a very powerful explosive but it cannot be used more extensively because of:

a. Its high cost of manufacture. Before the war it cost $.[illegible] to $1.00 per pound compared with $.14 to $.2[illegible] per pound for TNT. No doubt these costs have been reduced but the ratio is probably the same.

b. Its high melting point which prevents cast loading.

c. Its sensitivity.

Tetryl is very toxic.

2. TETRYTOL

This explosive was developed in this war to capitalize on the power of Tetryl and at the same time lower the melting point for cast loading and reduce the sensitivity for larger scale use. It is also known as Tetratol.

A. Properties

1. Tetrytol is light yellow in color.

2. It has a melting point of 65° to 90°C and is cast loaded at a density of 1.6.

3. As used it is generally manufactured from 75/25 Tetryl and TNT. Mixtures of 50%, 65% and 80% Tetryl and 50%, 35% and 20% TNT are also used to some extent.

The TNT melts and disolves part of the Tetryl forming a eutectic mixture of TNT and Tetryl and free Tetryl.

4. Explosive properties

a. Tetrytol has a drop test of 10" and will detonate from the impact of a bullet 20 to 35% of the time. It will detonate from temperatures of 179°-181°C.

b. It is about 20% stronger than TNT.

c. It detonates at a velocity of 7300 meters per second and has a brisance of 50.

B. The U.S. uses Tetrytol as a Paratroop and engineer Demolition Explosive due to the fact that 2½ lbs. will replace 3 lbs. of TNT. We also use it in some Anti-Tank Mines and as a Burster in Chemical ammunition.

The British use it as a Bursting charge in some bombs (not designated) and as a booster with the addition of wood meal to decrease the density and thereby increase the sensitivity.

C. It will exude at 65°C.

D. It is slightly corrosive to Steel, Aluminum, Copper, and Brass.

E. It is soluble in Acetone.

F. The addition of TNT permits melt loading and partially reduces the sensitivity but its cost remains high compared with TNT. It is too sensitive to be used in large ammunition and it is toxic.

It is 25% more efficient in shaped charges than TNT.

SECTION IV

NITROPHENOL BASED EXPLOSIVES

Nitrophenols are Benzene based explosives which, although more powerful than the Nitrotoluenes, have certain objections which caused them to be considered reserve explosives until shortage of Toluene has extended their use in this war.

1. DINITROPHENOL

$C_6H_3OH(NO_2)_2$

A. Properties

1. Color - light cream yellow

2. Form - it has a melting point of 114-115°C, so would be press loaded if used by itself.

3. Manufacture - it is manufactured by converting Benzene to Phenol and then nitrating or by the hydrolysis of Dinitrochlorobenzene.

4. Explosive properties

a. Sensitivity - about 17" in the drop test.

b. Strength - about [illegible] of TNT.

c. Velocity and Brisance - it detonates at about 5000 meters per second with a brisance figure of [illegible].

B. Dinitrophenol is used to lower the melting point of Picric Acid for melting (see Tridite).

C. It is entirely stable.

D. It forms dangerous salts with all metals but Aluminum and Tin.

E. It is soluble in Acetone.

F. It is very toxic.

2. TRINITROPHENOL

$C_6H_2OH(NO_2)_3$

Trinitrophenol was known as early as 17[illegible] but was used as a dye until 1869. In 1886 France adopted it as a standard bursting charge. Since then it has been used, in some form, by all nations. Around 19[illegible] it was relegated the position of a reserve explosive because of the superior qualities of TNT. In this war it is being used extensively by the [illegible] due to shortage of Toluene and an improvement in the manufacturing process.

It is known by the following names:

Picric Acid	U. S. and Britain
Lyddite	Britain (w[illegible])
Melinite	France
Pertite	Italy
Shimose	Japan
Shimosite	Japan
Granatfullung 88 (Grf 88)	Germany
Melinit	Germany
Cronite	Sweden

A. Properties

1. Picric Acid is a light, cream yellow in color.

2. It has a melting point of 1[illegible] [illegible] pressed although it can be cast by high pressure steam [illegible] a tendency on the part of field personnel to assume that any cast, yellow, Jap explosive is Picric Acid and to report it as such. This is probably not the case. Any cast, yellowish, Jap explosive [illegible] suspected of being Type 98 explosive which [illegible].

3. Picric Acid was manufactured by converting [illegible] and then nitrating. This was expensive compared to the manufacture [illegible]

of TNT and is one of the reasons for discontinuing its use. It is now manufactured by the Dinitrochlorobenzene process which is much cheaper.

4. Explosive properties

a. Picric Acid is somewhat more sensitive than TNT. It has a drop test of 12"-13" (14" for TNT). It detonates at [illegible]°C and from the impact of a bullet 24% of the time.

The casting of Picric Acid is apt to be dangerous as it tends to decompose slightly above its melting point. If melted and allowed to cool the crystalline structure tends to become distorted [illegible] internal stresses and increased sensitivity.

b. It is [illegible] stronger than TNT.

c. It detonates [illegible] figure of 45.

B. Picric Acid is used as a booster and bursting charge by all nations.

Specific uses follow:

1. United States - Navy booster
2. Britain - Grenades and [illegible]
3. France - Mines and Demolition charges.
4. Italy - Shells
5. Germany - Filler [illegible] tainers - Shells, Land Mines, [illegible].

Filler #5 - Granular - [illegible]

Filler #25 - Cast - Shells

Sub-booster in China when Germany [illegible].

It is a standard [illegible] and burster.

6. Japan - It is a standard booster [illegible].

It is a standard bursting charge in all types of [illegible] Shells, Bombs, Mines, Torpedoes, Land Mines, [illegible].

Charges.

C. Picric Acid is generally considered stable in storage but it has a tendency to decompose at tropical temperatures.

D. Picric Acid, as the name indicates, is an acid and has a corrosive effect on all metals except Aluminum and Tin. This results in the formation of Metallic Salts or Picrates, some of which are very sensitive, Primary Explosives (e.g. Lead Picrate and Iron Picrate have drop tests of 2" and 3-5" respectively) and others (Copper and Zinc Picrates) are more sensitive than Picric Acid itself.

For this reason Picric Acid must be protected from contact with its container. This is usually accomplished by coating the inside of the container with Acid proof material (e.g. Lacquer, Asphalt, etc.), or by loading the explosive in paraffined, cardboard containers.

In inerting ammunition loaded with Picric Acid care should be taken to avoid friction between the explosive and metallic surfaces in the presence of grit as this will cause detonation if sensitive Picrates are present.

E. Picric Acid is soluble in Alcohol and acetone and it can be disolved by the use of Sodium Carbonate or Sodium Sulfite.

F. Picric Acid has two advantages:

a. Its raw materials are plentiful.

b. It is more powerful than TNT.

Its main disadvantage is its high melting point.

It is somewhat toxic but not as bad as TNT in this respect.

4. TRIMONITE

A. Properties

1. This is a light cream yellow explosive.

2. It is cast loaded having a melting point of [illegible] 106°C.

3. It is manufactured from 70, 80, 90% Picric Acid and 30, 20, 10% Mononitronapthalene or Dinitronapthalene. It has a density of 1.6. The M NN mixtures have the lower melting point.

4. Explosive properties

a. The sensitivity varies with the amount of Picric Acid, ranging from 13" to 15.5" in the drop test compared with 14" for TNT. Trimonite will detonate from 0-10% of the time from the impact of a bullet and from temperatures of 300°-315°C.

b. The strength varies from 74% to 95% of TNT.

c. The velocity and brisance vary from 5000 to 6500 meters per second and 32 to 40.5 respectively.

B. Trimonite is used as follows:

1. United States - A reserve explosive to be used in case of shortage of TNT.

2. France - MMN - 70/30 - Picric Acid/Mononitronapthalene - Bombs.

MDN or MPDN - 80/20 Picric Acid/Dinitronapthalene - Bombs.

3. Japan - 50/50 and 80/20 - Picric Acid/Dinitronapthalene - Burster for Chemical shells and filler for Shells.

C. Stability - Same as Picric Acid.

D. It has the same reaction with metals as Picric Acid.

E. Solubility - Same as Picric Acid.

F. This is a cast explosive made from plentiful Benzene. It does not exude. It is inferior to TNT from an explosive standpoint losing power in the same proportion that MNN or DNN are added.

4. TRIDITE

This explosive is called Shellite by the British.

A. Properties:

1. Color - Light green yellow

2. Form - It is cast loaded, melting from 90-95°C. (Shellite 83°C).

3. Manufacture - From 60,70,80, and 90% Picric Acid and 40, 30, 20, and 10% Dinitrophenol. Shellite is 70/30. It is loaded at a density of 1.62.

4. Explosive properties:

a. The sensitivity of Tridite depends on the mixture. The drop test varies from 14" for the 60/40 to 12.5" for the 90/10 compared with 14" for TNT. Shellite is 14". The higher Picric Acid content mixture will detonate from a bullet about 20% of the time and from temperatures of 300°-315°C.

b. The strength varies from 90 to 100% of TNT. Shellite is about 91% of TNT.

c. The velocities and brisance vary from 6300 to 7000 meters per second and 36 to 43 respectively. The figures for Shellite are 6600 and 38.5.

B. Tridite is used as follows:

1. Britain - Shellite 70/30- Armor Piercing Bombs and Shells
2. France - DD - 60/40-Bombs and Shells
3. Italy - MBT 60/40-Shells

C. Stability - Same as Picric Acid.

D. Reaction with metals - Same as Picric Acid.

E. Solubility - Same as Picric Acid.

F. This combination is used to lower the melting point of Picric Acid for cast loading where it is necessary to use Picric Acid due to Toluene shortages.

Its disadvantage lies in the decreased power which results from the addition of Dinitrophenol.

It is difficult to see why the British use it in A.P. bombs as it is as sensitive as TNT and at the same time less brisant.

The mixture is more toxic than Picric Acid.

5. TRINITROPHENOL - TRINITROTOLUE MIXTURE

A. Properties:

1. Color - The same as TNT.

2. Form - Melting point of 80-90°C. permits casting.

3. Manufacture - From 60% Picric Acid and 40% TNT.

4. Explosive properties:

a. Sensitivity - Very slightly more sensitive than TNT (drop test about 13"-13.5"). It will probably detonate about 10% of the time from a bullet and at temperatures of 240-280°C.

b. Strength - About 3% greater than TNT.

c. Velocity and Brisance - About 7100 meters per second and 44 respectively.

B. Uses:

a. Italy - MAT - Shells

b. Japan - Bombs

C. It will exude, otherwise it is stable.

D. Will react with metals the same as Picric Acid but to a lesser degree.

E. It is soluble in Acetone.

F. The addition of TNT lowers the melting point of Picric Acid for cast loading and at the same time Picric Acid acts as an extender for the TNT.

It is less toxic than TNT.

SECTION V

AMMONIUM PICRATE BASED EXPLOSIVES

1. AMMONIUM PICRATE

$C_6H_2(ONH_4)(NO_2)_3$

This explosive is the Ammonia Salt of Picric Acid. It is also known as Explosive D and Dunnite.

A. Properties:

1. Explosive "D" varies in color. It may be lemon yellow, orange or reddish brown.

2. It is pressed into its container since it will not melt.

3. It is manufactured by neutralizing Picric Acid with Ammonium Hydroxide or Ammonia Gas. If excess Ammonia is present it will be orange to red in color. If it is deficient in Ammonia it will be lemon yellow.

4. Explosive Properties:

a. Explosive "D" is the most insensitive of military explosives. While a severe impact may detonate TNT, for all practical purposes, Explosive "D" will only detonate from the action of a suitable booster.

It will burn from the impact of a bullet [illegible]% of the time and this may finally cause detonation.

It detonates at temperatures of [illegible]°C.

Its sensitivity may increase with the formation of sensitive Explosive Salts after storage.

b. Explosive "D" is inferior to TNT in strength having only [illegible] of the strength of the latter.

c. It detonates at a rate of 6[illegible] meters per second and has a brisance figure [illegible].

B. Explosive "D" has been used by the United States in A.P. Ammunition, because of its insensitivity, since 1901.

C. It is hygroscopic and therefore unstable in storage.

D. In the presence of moisture it will hydrolize to Picric Acid which reacts with all metals.

E. Explosive "D" is soluble in water, warm Alcohol and Acetone.

F. It is an inferior explosive in every respect and is used only because of its insensitivity.

2. AMMONIUM PICRATE MIXTURES

In addition to its use by the United States, Ammonium Picrate is used in two mixtures: Picric Powder or Abel's Explosive by the British and Type One Explosive by the Japs. Very little information is available concerning Picric Powder.

A. Properties of Type One Explosive:

1. It is dark gray in color.

2. As it will not melt it is press loaded.

3. It is a mixture of Ammonium Picrate/Aluminum/Sawdust/Crude Petroleum 81/16/2/1.

4. Explosive Properties:

a. It is about equal to TNT in sensitivity.

b. Its strength is 36% greater than TNT.

c. It has a low rate of detonation (4300 meters per second) and a brisance figure of 36.

B. It is used by the Japs in Depth Charges.

C. The stability is on the same order as Ammonium Picrate.

D. The reaction with metals is the same as Picric Acid.

E. Solubility - Same as Ammonium Picrate.

F. While the addition of Aluminum makes this explosive very effective for underwater use, where the confinement of the water offsets the lack of brisance, it is difficult to understand why the Japs have gone to the trouble to convert Picric Acid to Ammonium Picrate for this purpose when Picric Acid would be a better all-around explosive.

A. Properties of Picric Powder:

1. Color - Same as Ammonium Picrate.
2. Form - Pressed.
3. Manufacture - 57/43 Potassium Nitrate/Ammonium Picrate.
4. Explosive Properties:
    a. Sensitivity - about the same as Tetryl.
    b. It is about 75% as strong as TNT.
    c. Velocity and brisance - No figures are available but it can be safely assumed that Picric P[illegible] is very inferior in this respect, probably detonating at about 5[illegible]00 meters per second.

B. It is used by the British as a booster in A.P. ammunition with Shellite.

C. Stability - Similar to Ammonium Picrate.

D. Reaction with metals - Similar to Ammonium Picrate.

E. Picric Powder is soluble in Acetone.

F. It is difficult to discern any particular advantage in this explosive. Tetryl would be a much more effective booster.

SECTION VI

HEXANITRODIPHENYLAMINE BASED EXPLOSIVES

1. HEXANITRODIPHENYLAMINE
$(C_6H_2)_2NH(NO_2)_6$

This is one of the many Benzene based explosives formally considered a reserve explosive but now being used due to a shortage of Toluene.

It is known by the following names: Hexil, Hexite, Hexanite, Hexamin, H.N.D., H.N.D.P., Dipicrylamine and Hexa (German).

A. Properties:

1. HND is deep yellow in color.

2. If used alone it will be pressed as its M.P. of 250°C prevents casting.

3. It is manufactured from Phenol or Dinitrochlorobenzene, Aniline and Nitric Acid and has a density of 1.58.

4. Explosive Properties:

a. Sensitivity - HND has a drop test of 9". It will detonate from the impact of a bullet 87% of the time and from temperatures of 237°-260°C.

b. Strength - It is about 15% stronger than TNT.

c. Velocity and Brisance - HND detonates at about 7200 meters per second and has a brisance figure of 45.

B. HND has been considered as a booster and, while it is inferior to Tetryl, it is superior to TNT for this purpose. It is now used by Germany and Japan in mixtures.

C. Stability - HND is entirely stable in storage.

D. Reaction with metals - None.

E. Solubility - HND is readily soluble in Acetone and in aqueous alkalies except KOH.

F. HND is similar in characteristics to Tetryl without having the power of Tetryl. It is slightly stronger than Picric Acid and does not have the latter's reaction with metals. Its wide use by Japan and Germany indicates that it is probably easier to manufacture than Picric Acid. It is extremely toxic.

2. HEXANITE

This is one of the principle HN derivatives. It is called Hexanite by the U.S. Navy and NTD_2, Schiesswolle 18 and TSMV 1-101 by the Germans.

A. Properties:

1. Color - Greenish gray

2. Form - It has a melting point of about 80-90°C so is usually cast loaded.

3. It is manufactured from TNT/HND/Aluminum 60/24/16. Its density is 1.72.

4. Explosive Properties:

a. Sensitivity - It has a drop test of 10", detonates from the impact of a bullet and from temperatures of 200-260°.

b. Strength - It is about 30% stronger than TNT due to the addition of Aluminum.

c. Velocity and brisance - It detonates at about 6900 meters per second and has a brisance figure of .

B. It is used by Germany in Mines, Depth Charges, Torpedoes and in Naval Demolition Containers.

Japan uses it in Torpedoes. Reports have stated that it is used by Britain but this has not been verified by reports on specific ammunition.

C. It is entirely stable.

D. It has no reaction with metals.

E. It is readily soluble in Acetone.

F. The addition of TNT to this mixture lowers the sensitivity of HND and permits cast loading. The addition of aluminum does not affect the brisance materially but does increase the strength by 30% resulting in a very powerful explosive. It also increases the incendiary effect of the explosive because of the brilliant flash from the Aluminum on detonationl It compares with TNT/Aluminum, mixtures as follows:

Advantages: 1. Greater strength
2. Greater brisance
3. Extends TNT
Disadvantages: 1. Sensitivity
2. Toxicity

3. NOVIT

This is another HND derivative. It is called Hexamit and Novit by the Germans and Type 97 Explosive by the Japs.

A. Properties:

1. Its color is a slightly lighter yellow than HND.
2. Its melting point is 80-90°C permitting cast loading.
3. It is a mixture of 60/40 TNT/HND.
4. Explosive Properties:
    a. Novit has a drop test of 11.5" and will detonate from bullet impact and from temperatures of 237-260°C.
    b. It is about 6-9% stronger than TNT.
    c. It detonates at 7000 meters per second and has a brisance value of 44.

B. It is used by Germany and Japan in Torpedoes and Mines.

C. It is entirely stable.

D. It has no reaction with metals.

E. It is readily soluble in Acetone.

F. Novit, while a slightly better explosive than TNT, is used mainly as an extender of TNT. It has the disadvantages of sensitivity and toxicity.

SECTION VII

TRINITROANISOLE BASED EXPLOSIVES

1. TRINITROANISOLE

$C_6H_2OCH_3(NO_2)_3$

This explosive was developed to overcome Picric Acid's high melting point and tendency to react with metals. It is called Type 91 **Explosive by the Japs, Ansole** by the Germans and is frequently abbreviated **to Anisole.**

A. Properties:

1. **Anisole is colorless when pure** but when found it will appear **white. After** exposure to light it becomes dirty yellow.

2. **Its melting point of** 64° to [illegible] permits cast loading at a **density of 1.4.**

3. **Anisole is the** Methyl Ether of Phenol. Formerly the manufacture consisted in converting Benzene to Phenol to Anisole and **nitrating.** This was expensive and dangerous.

It is now easily made by treating Dinitrochlorobenzene with Sodium **Methylate** and then nitrating.

4. Explosive properties:

a. It is less sensitive than TNT having a drop test of **15-16".** It will not detonate from the impact of a bullet and requires a temperature of 165°-296°C to detonate.

b. It is about as strong as Picric Acid.

c. Its velocity and brisance are about the same as TNT (6900 meters per second and 43).

B. It is used by the Japs in Armor Piercing bombs and shells.

C. It is unstable. In the presence [illegible] moisture it will hydrolyze to Picric Acid.

D. It has the same reaction with metals as Picric Acid after hydrolysis.

E. It is soluble in Acetone.

F. Anisole has the following advantages as an A.P. filler:

a. It is equal to TNT in explosive qualities.

b. It can be cast.

c. Its raw materials are plentiful.

Its disadvantages are :

a. If it hydrolizes to Picric Acid it will not only react with metals but will become too sensitive for use as an A.P. filler.

b. Its low melting point will cause it to exude at elevated temperatures.

c. It is very toxic.

2. HEXANITE-ANISOLE MIXTURE

This mixture is called Type 98 Explosive by the Japs.

A. Properties:

1. This explosive is greenish yellow when cast and lemon yellow when pressed.

2. Its melting point of 69 to 70°C permits cast loading.

3. It is manufactured from 60% Trinitroanisole and 40% Hexanitrodiphenylamine.

4. Explosive properties:

a. Its sensitivity is similar to that of Picric Acid (drop test of 12.5"). It detonates at temperatures of 237°-240°C and from the impact of a bullet about 20% of the time.

b. It is about 9% stronger than TNT.

c. It detonates at a velocity of 7000 meters per second and has a brisance of 44.

B. It is used by the Japs in the cast form as a bursting charge in all types of Naval Ammunition: Bombs, Shells, Mines, etc., and has replaced Picric Acid to a great extent. It is used in the pressed form as an Auxiliary Booster.

C. Stability - Same as Trinitroanisole.

D. Reaction with metals - Same as Trinitroanisole.

E. It is soluble in Acetone.

F. This mixture has the following advantages:

a. Both explosives are based on Benzene.

b. The sensitivity and high melting points of HND are overcome.

c. The melting point objection to Picric Acid is overcome.

d. The tendency of Anisole to exude is reduced and the power increased.

Its main disadvantage are:

a. Lack of stability.

b. Toxicity.

c. The mixture will probably detonate from the impact of a bullet at least part of the time.

3. NITROLIT

A. Properties:

1. Color - White to light yellow.

2. Form - Cast loaded: Melting point around 75°C.

3. It is manufactured from 60/40 Trinitroanisole/Ammonium Nitrate.

4. Explosive Properties:

a. Sensitivity - Similar to 60/40 Amatol

b. Strength - Similar to 60/40 Amatol

c. Brisance - Similar to 60/40 Amatol

B. It is used by Germany in Mines and Torpedoes.

C. It is hygroscopic and the Anisole will hydrolize to Picric Acid.

D. It has the same reaction as Picric Acid after hydrolysis

E. It is soluble in Acetone.

F. This is an Amatol Type explosive using Trinitroanisole instead of TNT. It utilizes plentiful Benzene but is toxic and less stable than Amatol.

SECTION VIII

NITROBENZENE BASED EXPLOSIVES

1. DINITROBENZENE

$C_6H_4(NO_2)_2$

This explosive is frequently called DNB. The Germans name it DI or Dinitrobenzol.

A. Properties:

1. DNB is yellowish in color.
2. It has a melting point of 89-90°C and can be cast.
3. It is manufactured from Benzene and Nitric Acid or by reduction of Dinitrochlorobenzene.
4. Explosive properties:
    - a. Its sensitivity is about equal to that of explosive D. (18" drop test). It will not detonate from the impact of a bullet and does not detonate from temperatures up to 560°C.
    - b. It is inferior in strength being about 85% as strong as TNT.
    - c. It has a low velocity of detonation (6000 meters per second) and a brisance figure of about 5..

B. It is used by the Germans as a desensitizer for RDX ([illegible]).

C. It is entirely stable.

D. It has no reaction with metals.

E. It is soluble in Acetone and Alcohol.

F. Advantages of DNB:

a. Its raw materials are comparatively plentiful.

b. It is an extender and desensitizer for other explosives.

c. It has a low melting point for cast loading.

Disadvantages of DNB:

a. Low strength and brisance.

b. It is extremely toxic.

2. TRINITROBENZENE $C_6H_3(NO_2)_3$

A. Properties:

1. TNB is yellowish in color.

2. It has a melting point of 121-123°C and cannot be cast.

3. It is manufactured by reducing Trinitrochlorobenzene or by nitrating DNB.

4. Explosive Properties:

a. TNB has about the same as or slightly less sensitivity than TNT (14-15" by the drop test). It will not ordinarily detonate from the impact of a bullet or at heats up to 360°C.

b. It is about 11% stronger than TNT.

c. It detonates at 7400 meters per second and has a brisance figure of 47.

B. It is used by the Germans as filler #70. The exact use is not stated.

C. It is entirely stable.

D. It has no reaction with metals.

E. It is soluble in Alcohol and Acetone.

F. TNB has very fine explosive qualities but is not used more because of the difficulty of nitration and consequent low yield. Its use definitely indicates a shortage in raw materials. It is very toxic.

3. TRINITROCHLOROBENZENE
$C_6H_2Cl(NO_2)_3$

This explosive is also called Picryl Chloride and abbreviated to TNCB.

A. Properties:

1. TNCB is an almost colorless explosive.

2. Its melting point of 81-83°C permits casting.

3. It is manufactured by nitrating Dinitrochlorobenzene. This is almost as difficult as adding the third Nitro group to DNB and the yield is very low.

4. Explosive Properties:

a. TNCB has about the same sensitivity as or slightly less sensitivity than TNT (14.5" drop test).

b. It is about 6% stronger than TNT.

c. It has about the same velocity and brisance as TNT.

B. It is used by the Germans as a shell filler.

1. Filler #60 pressed

2. Filler #61 cast

German markings are a yellow container with a diagonal white stripe.

C. It is entirely stable.

D. It has no reaction with metals.

E. It is soluble in Alcohol and Acetone.

F. The use of TNCB by the Germans indicates a shortage of TNT. It is extremely toxic.

TRINITROCHLOROBENZENE - AMMONIUM NITRATE

This combination is designated Filler #64 by the Germans.

A. Properties:

1. The color would vary from white to brown depending on the condition of the Ammonium Nitrate.

2. It has a melting point of 81-82°C and normally would be cast loaded.

3. It is manufactured from TNCB/Ammonium Nitrate 60/40.

4. Explosive Properties:

   a. Sensitivity - Same as 60/40 Amatol.

   b. Strength - Same as 60/40 Amatol.

   c. Velocity and brisance - Same as 60/40 Amatol.

B. It is used by the Germans as a shell filler.

C. It is hygroscopic and therefore unstable.

D. It reacts with metals much the same as Amatol.

E. It is partially soluble in water and soluble in Alcohol and Acetone.

F. This mixture substitutes TNCB for TNT in an Amatol type explosive due to a shortage of TNT. The mixture is very toxic.

SECTION IX

MISCELLANEOUS AROMATIC NITRO COMPOUNDS

1. TRINITROCRESOL

$C_6HCH_3(OH)(NO_2)_3$

This is an inferior explosive used by the Italians as an ingredient of other explosives. It is of little interest as it is not used by itself.

2. AMMONIUM TRINITROCRESYLATE

$C_6HCH_3(NO_2)_3ONH_4$

This explosive is also known as Ecrasite. It is the Ammonium Salt of Trinitrocresol.

A. Properties:

1. Color - Yellow to reddish yellow.

2. Form - It has a melting [illegible] of 100°C and is cast loaded.

3. It is manufactured by treating Trinitrocresol with Ammonium Hydroxide or Ammonia Gas.

4. Explosive Properties:

a. Sensitivity - Same order as Explosive "D".

b. Strength - About 90% of TNT.

c. Velocity and Brisance - Inferior - about 6000 meters per second with a brisance figure of about 32.

B. It is used by the Italians in large shells.

C. It is somewhat hygroscopic.

D. It has no reaction with metals.

E. It is soluble in water, Alcohol and Acetone.

F. This is an old World War I explosive used because of a shortage of raw materials. The fact that it can be cast is its one advantage.

3. NITRONAPTHALENES

Napthalene is obtained in large quantities from coal coking and, since it is easy to nitrate, every effort has been made to utilize it as a military explosive.

A. NAPTHALENE
$C_{10}H_8$

This material is used as a fuel when an excess of oxidizing agent is present (see Ammonals).

B. MONONITRONAPTHALENE
$C_{10}H_7NO_2$

This material is manufactured by nitrating Napthalene. It is yellow in color and has a melting point of [illegible]. It is [illegible] lower the melting point of Picric Acid for cast loading (See Picric Acid). It is not an explosive.

C. DINITRONAPTHALENE $C_{10}H_6(NO_2)_2$

This material has a very feeble capacity for explosion. It is yellowish in color, has a melting point of 140°C and is manufactured by nitrating Napthalene.

It is used either as a mild sensitizer for Ammonium Nitrate or as an extender for TNT.

Specific uses follow:

Explosive	Nation	Composition	Use	Remarks
Schneidcrite	Italy	NH_4NO_3/DNN 87/13	Shells	Sensitizer
Nougat (MST)	Italy	NH_4NO_3/DNN/TNT 50/7/43	Shells	Extender
Siperite (MNDT)	Italy	NH_4NO_3/DNN/TNT 72.8/10.5/16.7	Shells	Extender
	Italy	TNT/DNN	Shells	Extender
	Germany	TNT/NH_4NO_3/DNN	Not stated	Extender
	Germany	TNT/DNN	Not stated	Extender
	Germany	TNT/NH_4NO_3/DNN 35/50/15	Not stated	Extender
Shonayaku	Japan	NH_4NO_3/DNN	Not stated	Sensitizer
Chanayaku	Japan	TNT/DNN 70/30	Shells	Extender

The addition of DNN to TNT reduces the explosive values and decreases the sensitivity of the latter and is used due to a shortage of raw materials.

Its addition to Ammonium Nitrate does not eliminate the necessity or a high explosive sensitizer, which would usually take the form of an auxiliary booster, to insure a high order detonation.

D. TRINITRONAPTHALENE
$C_{10}H_5(NO_2)_3$

TNN has about the same sensitivity as TNT but is inferior in explosive qualities being between Dinitrotoluene and Dinitrobenzene in this respect. It is yellow in color, melts at 220°C and is manufactured by Nitrating Napthalene.

Some specific uses follow:

Explosive	Nation	Composition	Uses
Sabulite	Italy	NH_4NO_3/TNN/Calcium Silicate/$N_aNO_3$60/3/14/18	Shells
Sabulite	Italy	NH_4NO_3/TNN/Calcium Silicate 65/10/25	Shells
Viberite	Italy	NH_4NO_3/N_a[illegible] 42/40/18	Shells
Piombite	Italy	Lead Nitrate/TNN/Lead Carbonate/Calcium Silicate/ Vaseline 75/15.75/1.50/5.75/2	Shells

In the above Mixtures TNN is used as a substitute sensitizer for TNT. Calcium Silicate is often mentioned as a substitute for Aluminum. Lead Nitrate and Sodium Nitrate are oxidizing agents and Lead Carbonate is a fuel. All are low grade explosives used due to a shortage of raw materials.

E. TETRANITRONAPHALENE
$C_{10}H_4(NO_2)_4$

This is a very powerful explosive but is too expensive for general use.

4. TRINITROXYLENE
$C_6H(CH_3)_2(NO_2)_3$

A. Properties:

1. Color - Golden yellow.
2. Form - pressed - melting point 182°C.
3. Manufacture - Nitration of Xylene.

4. Explosive Properties:

a. Sensitivity - Drop test 21" (TNT 14"). It detonates at 410°C. It will not propogate the detonating wave.

b. Strength - About 88% of TNT.

c. velocity and brisance - 37[illegible] meters per second and 15.

B. TNX is used by the Germans as a sensitizer for a low grade explosive in Grenades. Filler #57 Abonachit 2 - Ammonium Nitrate/Potassium or Sodium Nitrate/TNX/Collodion Cotton/Sodium Chlorate. 64/3/12-14/1/17-19. It is indicated by a green container with a brown stripe.

C. TNX is stable.

D. It has no reaction with metals.

E. It is soluble in Acetone.

F. TNX is an inferior explosive and difficult to nitrate. In the German explosive it may be used due to a shortage in TNT or to avoid the disruptive effect TNT would have on a grenade.

CHAPTER 7

ALIPHATIC NITRATES

SECTION I

CYCLOTRIMETHYLENETRINITRAMINE BASED EXPLOSIVES

1. CYCLOTRIMETHYLENETRINITRAMINE

$(CH_2)_3N_3(NO_2)_3$

This explosive was patented in Germany in 1899 as a medicine. It was patented as an explosive in 1920 in Britain and in 1922 in the United States. It is one of the so-called super-explosives which have come into prominence during the present war. It is known by the following names:

Cyclonite	United States
RDX (Research Department Explosive)	Britain
T4	Italy
Hexogen (H)	Germany
Tanoyaku	Japan

A. Properties:

1. RDX is a white explosive.

2. It is not cast loaded as it [illegible] melting point of [illegible]°C.

3. It is manufactured synthetically from coal, air and water which are used to manufacture Formaldehyde, Ammonia and Nitric Acid. Formaldehyde and Ammonia are condensed to form Hexamethylenetetramine (Hexamine) which is nitrated to RDX. Earlier use of RDX was prevented by large Methyl Alcohol requirements and the fact that it requires eleven pounds of Nitric Acid to produce one pound of RDX. It is difficult to recover the Nitric Acid after manufacture due to the reaction of liberated Formaldehyde and the spent acid. The first obstacle has been overcome by the production of synthetic Methyl

Alcohol and the second partially overcome by improved manufacturing processes.

4. Explosive Properties:

a. RDX is slightly more sensitive than Tetryl. The drop test is 7" against 8" for Tetryl. It will detonate 100% of the time from the impact of a rifle bullet and at temperatures of 197° to 260°C.

b. It is 62% stronger than TNT.

c. It detonatee at 8400 meters per second and has a brisance figure of 61.

B. RDX is used mainly in mixtures but it is used by itself as a sub-booster, booster and bursting charge as follows:

1. Italy: Sub-booster - All types of ammunition
   Booster - Shells
   Bursting Charge - Land Mines
2. Germany: Filler #89 - Cast-in mixtures
   Filler #90 - Pressed-in mixtures
   Bursting charge in small caliber Shells (e.g. 4.2cm) and Rifle Grenades.
3. Japan: Booster - small ammunition
   Sub-booster - Bomb Fuzes
   Bursting Charge - 20 MM and 37 MM shells - 50 calib and 7.7 MM. Bullets - Land Mines. It is often reported used with Aluinum. This is not a mixture but the Aluminum is added for incendiary effect.

C. RDX is entirely stable.

D. It has no reaction with metals.

E. It is soluble in Acetone and may be hydrolized by Sodium Hydroxide at 60°C or by boiling in Dilute Sulphuric Acid.

F. The chief advantages of RDX are its tremendous power and the fact that it uses non-strategic raw materials. Its disadvantages are its high melting point, its sensitivity and the low yield in manufacture.

At present all nations are devising means of utilizing RDX in a desensitized form. It is either combined with Nitrohydrocarbons, which also permit cast loading, or with waxes or oils for press loading.

This explosive is especially attractive to the Axis because of their raw material shortages.

2. CYCLOTRIMETHYLENETRINITRAMINE - WAX MIXTURES

This is one form by which RDX is desensitized for wider use. Composition A is our name for this type of mixture.

A. Properties:

1. The color of the mixture depends on the wax. Composition A is white to buff. German compositions are white or blue and Ital[illegible] are white or red due to the use of dye.

2. RDX/Wax is press loaded. The addition of wax does not reduce the melting point.

3. It is manufactured from RDX and varying percentages of wax. Composition A is 91/9 RDX/Beeswax. German and Italian mixtures use Montan Wax (Lignite Wax).

4. Explosive Properties:

a. The sensitivity depends on the amount of wax and whether it coats the individual grains or not. Our composition A has a drop test of 14" the same as TNT. It does not detonate from the impact of bullet and requires a temperature of 250°C to detonate. Figures are not available for the various foreign mixtures but generally the [illegible] will indicate the order of sensitivity.

b. Composition A is about 30 [illegible] stronger than TNT. Other mixtures vary with the amount of wax.

c. Composition A detonates at 7500 meters per second and has a brisance figure of 49.6.

B. RDX/Wax is used as a booster with a small amount of wax which does not coat the grains and as a bursting charge with larger amounts which act as a grain coating. Specific uses follow:

1. United States: Composition A - Shells.
2. Britain: Shells and Grenades
3. Italy: Boosters (dyed red) RDX/Wax 95/5.
4. Germany: Filler #86 - A core of RDX/Wax acting as an auxiliary booster for EDD (See) in 75 MM A.P. Shells.

   Filler #91 - H5 - RDX/Wax 95/5 - Sub-booster and Booster.

   Filler #92 - H10 - RDX/Wax 90/10 - Booster.

   RDX/Wax 89.7/10.3 - 75 MM A.P. Shells.

   RDX/Wax - 97/3 - Used as a sub-booster in the tropics in place of PETN/Wax.

   It is also used as a filler in Grenades and Shaped Charges.
5. Japan RDX/Beeswax- 85/15 - Bursting charge, 75 MM Shells.

   RDX/Beeswax- 92/8 and 95/5 Bursting charge 20 MM Shells. (Jap RDX/Wax is white to buff)

C. RDX/Wax is entirely stable.

D. It is slightly corrosive to Steel, Magnesium, Copper and Copper Alloys.

E. The solubility is the same as RDX. It would be dangerous to attempt to melt RDX/Wax fillings as only the wax would melt leaving the very sensitive RDX.

F. RDX/Was is not a particularly desirable filling as the wax does not enter into the detonation and therefore reduces the velocity. In burning it also robs the explosive of its Oxygen reducing strength.

Used as a booster, with small amounts of wax, it is sufficiently insensitive and very satisfactory.

3. Cyclotol

This is the most popular RDX derivative in present use. The United States Cyclotol is called Composition B. The Italians call it Tritolite.

A. Properties:

1. The color of Cyclotol varies depending on the TNT. It may range from dirty white to light yellow to brownish yellow.

2. It is cast loaded, melting between 85° and $100^{\circ}C$.

3. It is manufactured from TNT, RDX and sometimes wax. Our composition B is RDX/TNT/Beeswax, 59/40/1 and B_2 is 60/40 RDX/TNT. Foreign nations use other percentages, 50/50 being the most popular.

Composition B is loaded at a density of 1.62.

4. Explosive Properties:

a. Composition B has a drop test of 11" and will detonate 20% of the time from the impact of a bullet. It detonates at temperatures of $188^{\circ}-270^{\circ}C$.

b. It is about 35% stronger than TNT.

c. It has a velocity of 7800 meters per second and a brisance figure of 51.8.

B. Cyclotol is used by all nations as a bursting charge in ammunition that will not have to penetrate the target.

Specific uses follow:

1. United States: Composition B and B2 - Large General Purpose Bombs and the 90 and 260 lb. Fragmentation Bombs. It imparts higher velocities, to smaller fragments, than for TNT loaded bombs.
2. Britain: Composition B - Has been mentioned as a booster. It is used as a bursting charge in General Purpose, Medium and High Capacity, Anti-submarine, Fragmentation and Parachute Bombs and in Shells.
3. Italy: 50/50 - RDX/TNT - Bursting charge in Hollow Nose ammunition and Land Mines.

   60/38/2 - RDX/TNT/Wax (dyed red) - Anti-tank Bombs.
4. Germany: Filler #18 - FP02/H5-80/20 - TNT/RDX/Wax - 80/19/1 - Shells

   Filler #95 - H/FP02 - RDX/TNT - 60/40 - Pressed-Bursting charge for Shells.

   RDX/TNT 50/50 and 53/47 - Hollow Nose ammunition, Shells, Grenades and Demolition Charges.

   RDX/TNT/Wax - 51/48/1, 58/40/2, 57/40/3, 55/42/3 - Shells.

   RDX Pellets embedded in TNT - 4000 lb. Bomb.
5. Japan: RDX/TNT 60/40 or 50/50 General Purpose, Anti-aircraft and Anti-Personnel bombs, Land Mines, Shells and Demolition Charges.

C. Cyclotol is entirely stable.

D. It corrodes Steel, Magnesium, Copper and Copper Alloys very slightly.

E. It is soluble in Acetone.

F. This is a much better explosive than Composition A. It is more powerful due to the active desensitizing agent and it can be cast loaded.

Its main disadvantage is its sensitivity and, from the Axis' standpoint, its use of TNT.

The following figures compare its efficiency with TNT:

	Peak Pressure	Impulse	Water Shock	Shaped Charge Efficiency
TNT	100	100	100	100
Cyclotol	110	110	123	169

4. PLASTIC CYCLOTRIMETHYLENETRINITRAMINE EXPLOSIVES

A. Composition C.

In commercial blasting gelatin dynamite is used extensively because of its density and plasticity. It can be moulded to any form desired. Since it is too sensitive for Military use a substitute had to be devised. The answer was RDX and Oil which we call Composition C and the British call Plastic High Explosive.

1. Properties:
    a. This is a brown explosive.
    b. It is plastic in form and very much like putty.
    c. It is manufactured from 88/11.4/.6 RDX/oil/Lecithin (helps prevent formation of large crystals increasing the sensitivity).

Jap P.H.E. is 80/85% RDX and 20-15% oil.

It has a density of 1.50.

d. Explosive properties:

1. Composition C has about the same sensitivity as TNT. (14" drop test). It will not detonate from the impact of a bullet. It requires temperatures of 177 to 285°C to detonate, depending on its physical state.

2. It is 20 to 30% stronger than TNT.

3. It detonates at 7400 meters per second and has a brisance of 46.5.

2. It is used by Britain, Germany and Japan as a Demolition Agent. It is obsolete as far as the United States is concerned.

3. Composition C is unstable. It retains its plasticity from 32° to 100°F. Below 32°F it becomes brittle and insensitive and above 100°F it becomes gummy and the oil tends to leak out, leaving pure RDX which is too sensitive for front line work.

4. It is not reactive with metals.

5. It is soluble in Acetone.

6. In addition to its lack of stability, composition C loses effectiveness because Oil is an inert material which reduces velocity and strength. It is 21% more efficient, in shaped charges, than TNT.

B. Composition C^{2}

This plastic explosive was developed to overcome the objections to Composition C.

1. Properties:

a. It is a brownish yellow in color.

b. In form it is a putty like plastic.

c. It is manufactured from the following ingredients:

RDX	80.1%
Mononitrotoluene	4.0%

Dinitrololuene	10.0%
Trinitrotoluene	4.0%
Collodion Cotton	1.0%
Dimethylformamide	.9%
	100.0%

The Nitroloiuenes desensitize the RDX and the reaction of Collodion Cotton and the solvent forms a gelatin. The German version, called Plastite, contains RDX/Nitrohydrocarbons/Collodion Cotton 64/32.5/3.5.

d. Explosive Properties:

1. Composition C^2 is more sensitive than Composition C having a drop test of 12.5" compared with 14" for TNT. It is affected 20% of the time by the impact of a bullet and detonates from a heat of 172° to 285°C depending on its state.

2. It is about 35% stronger than TNT.

3. It detonates at 8000 meters per second and has a brisance of 55.

2. It is used by the United States and Germany as a demolition charge. We also use it in the 7.2 rocket.

3. It is more stable than Composition C, retaining its plasticity from -20° to 125°F. There is no danger that the desensitizer will leak out. It will set up and lose its plasticity from hot storage conditions due to evaporation of volatile matter.

4. It has no reaction with metals.

5. It is soluble in Acetone.

6. This is a more effective explosive than Composition C principly because only .9% of the explosive is inert as against 12% for Composition C.

Due to the presence of TNT it is somewhat toxic and should not be handled without gloves.

The German Plastite would be a less effective explosive in every respect due to the reduced RDX content.

C. Composition C^3

At the present time the United States plans to replace Composition C^2 with Composition C^3. In C^3 3% RDX is replaced by 3% Tetryl and the Dimethylformamide by Mononitrotoluene. It is hoped that this will increase the stability of Composition C^2.

The other characteristics of the explosive remain the same.

5. TORPEX

This is the most powerful of the RDX mixtures. The Germans call it Trialen. Tetranol or Trialine.

A. Properties:

1. Torpex is a slate gray in color.

2. Its melting point of 88-95°C permits cast loading.

3. It is manufactured from RDX, TNT and Aluminum in varying percentages. It loads at a density of 1.73. In some cases a small percentage of wax is added as a desensitizer.

4. Explosive Properties:

a. It is slightly less sensitive than Tetryl having a drop test of 8-9" as compared to 8" for Tetryl. It will detonate from the impact of a bullet from 52% to 100% of the time and from temperatures of 185 to 220°C.

b. It is a very strong explosive being 40% stronger than TNT. When confined underwater it is 50% stronger by weight and [illegible]% stronger by volume.

c. It detonates at 7300 meters per second, and has a brisance figure of 57.9.

B. Torpex is used mainly, in underwater explosives, as a bursting charge. Specific uses follow:

1. United States - Torpex I - RDX/TNT/Al 45/37/18

   Torpex I - RDX/TNT/Al/ Beeswax 44/37/18/1

   Torpex II- RDX/TNT/Al 42/40/18

   Torpex is used in Depth Bombs, Depth Charges, Torpedoes and the 7.2 rocket.

2. Britain - Torpex I and II - Medium Capacity and Anti-submarine Bombs; Aerial and Submarine Torpedoes; and Rockets.

3. Germany - Filler #105 - Trialen- RDX/TNT/Al 15/[illegible]/15 or 16/70/12 - General Purpose Bombs and Torpedoes.

   Filler #106 - Trialen- RDX/TNT/Al/25/[illegible]/25 - Bombs

4. Italy - Trialen 105 - Torpedoes.

C. Torpex is entirely stable.

D. It reacts slightly with Brass.

E. It is soluble in Acetone.

F. The addition of Aluminum gives this explosive tremendous power, especially under water, even though it affects the velocity of detonation somewhat.

Figures comparing its effect with TNT follow:

Explosive	Peak Pressure	Impulse	Water Shock
Torpex	122	127	141
TNT	100	100	100

Its chief disadvantage is its sensitivity. It will detonate on a hard surface from a fall of 2000 to 2500 feet or a terminal velocity of 350-450 feet per second or on any surface from a 10,000 foot drop.

6. DEPTH BOMB EXPLOSIVE

This explosive was developed, as a result of a number of accidents caused by the sensitivity of Torpex, for use in Depth Bombs. It is commonly called DBX.

A. Properties:

1. DBX is a gray explosive.

2. Its melting point (between 80° & 90°C) permits cast loading.

3. It is manufactured from RDX/Ammonium Nitrate/TNT/Aluminum 21/21/40/18. In other words, 21% of Ammonium Nitrate is substituted for RDX. A variation of DBX is called Minox and consists of RDX/NH_4NO_3/TNT/Al 5-15/25-35/40/20. It is not being used at present. DBX loads at a density of 1.68.

4. Explosive Properties:

DBX is intermediate between Torpex II and Minol II.

a. It has a drop test figure of about 10"(11" for Monol II, 9" for Torpex). It will detonate from the impact of a bullet 49% of the time. It will probably detonate from a temperature of about 200°C.

b. It is 46% stronger than TNT.

c. It detonates at [illegible] meters per second and has a brisance figure of about 48.

B. It is used by the U. S. and Britain in Depth Bombs.

C. Due to the inclusion of Ammonium Nitrate it would be somewhat hygroscopic and therefore not entirely stable. It would tend to have the same type of stability as Amatol and Ammonal.

D. The reaction with metals would be much the same as Amatol and Ammonal.

decreased sensitivity. A comparison of four explosives follows:

Explosive	Energy of Air Blast	Energy of Water Shock
TNT	100	100
DBX	158	144
Minol	135	138
Torpex	146	141

It will be noted that the addition of Ammonium Nitrate gives a better effect when the explosive is confined.

7. PTX-1

This is an experimental explosive designed to overcome the sensitivity of Tetrytol and its tendency to exude.

A. Properties:

1. This is a light yellow explosive.
2. It is cast, having a melting point of 90-9[illegible].
3. It is manufactured from 30/50/20 RDX/Tetryl/TNT.
4. Explosive Properties:

a. This explosive is supposed to eliminate some of the sensitivity of Tetrytol. In view of the fact that the TNT content of Tetrytol is reduced and RDX is substituted for a certain portion of the Tetryl it is difficult to see how this could be true. This contention is verified by impact tests with a rifle bullet. PTX-1 detonates partially 20% of the time and completely 20% of the time while [illegible] Tetrytol does not detonate at all and 75% detonates [illegible] of the time.

b. It is about 3[illegible] stronger than TNT.

c. It detonates at 7400 meters per second and has a brisance figure of 52. This is slightly better than Tetrytol.

B. It is proposed to use this explosive in place of [illegible]. Tests are now under way to determine its suitability for [illegible] [illegible]nition.

C. It is stable in stora

D. Its reaction with metals is the same as Tetrytol.

E. It is soluble in Acetone.

8. P T X - 2

This is an experimental explosive designed to overcome the sensitivity of Pentolite.

A. Properties:

1. It is a dirty white to light buff in color.

2. It is cast loaded, melting at 95°C.

3. It is manufactured from 43.2/28/28.8 RDX/PETN/TNT.

4. Explosive Properties:

(a) PTX-2 is slightly less sensitive than Pentolite. It has a drop test figure of 10" and is detonated by the impact of a bullet 60% of the time.

(b) It is about 45% stronger than TNT.

(c) It detonates at 8000 meters per second and has a brisance figure of 54.5.

B. It has the same status as PTX-1.

C. It is more stable than Pentolite.

D. The reaction with metals would be somewhat the same as Pentolite but to a lesser degree.

E. It is soluble in Acetone.

F. This explosive, if present conclusions are verified by field tests, seems to be not only less sensitive than Pentolite but more brisant.

9. MISCELLANEOUS CYCLOTRIMETHYLENETRINITRAMINE EXPLOSIVES

In the rush to capitalize on the power of RDX, and/or the fact that it requires no strategic raw materials, various nations have designed quite a few mixtures, none of which are used very widely. Complete figures are not available on most of these, but they will be discussed briefly in the following paragraphs:

A. Amatex:

Amatex is a yellow, cast, British Exolosive used in large General Purpose; Medium and High capacity; and Anti-submarine Bombs. It consists of Ammonium Nitrate/TNT/RDX 50/41/9 and is generally called Amatex 9.

Essentially it consists of Amatol 60/40 with the addition of 15% Composition B to eliminate the tendency, of large Amatol filled Bombs, toward Low Order Detonation.

Its characteristics would be those of Amatol 60/40 with the sensitivity, strength and brisance slightly increased.

Amatex 5 and 25 (TNT/RDX/AN [illegible]) have been mentioned but we have no record of their actual use.

B. German Filler #52 is a yellow, cast explosive manufactured from Dinitrobenzene/Ammonium Nitrate/RDX 50/35/15. This is an Amatol type explosive with the inferior DNB used in place of TNT, due to a shortage of the latter. The insensitivity of DNB is compensated for by the addition of RDX.

This explosive would have much the same characteristics as [illegible] Amatol. It is used in 50 Kg. G.P. and S.A.P. bombs. It is very [illegible].

C. German Filler #5[illegible] ( ) - This is a white pressed explosive manufactured from Calcium Nitrate/Ammonium Nitrate/RDX [illegible]. [illegible] another Amatol type explosive sensitized by RDX instead of TNT. Calcium Nitrate is a cheap oxidizing agent without any explosive properties. The sensitivity whould be about that of 50/50 Amatol but the explosive properties are inferior. It is used as a [illegible] filling in [illegible] and Robot Bombs with a surround of Filler #52. Evidently the Calcium Nitrate is designed to overcome the Oxygen deficiency of Filler #52.

D. <u>German Filler #45</u> - Pressed - NP 30/H 50/50 - PETN/RDX/Wax 35/50/15 - This filler is used in special projectiles. It should be similar in characteristics to Composition A.

E. <u>Jap Filler for 50 caliber and 7.7 MM bullets</u>, RDX/PETN 87/13 and 42/58. The characteristics are the same as RDX or PETN used separately. It is press loaded.

F. <u>Jap Type 94 Explosive.</u> This is a cast white explosive manufactured from 40/60 RDX/Trinitroanisole. Its explosive properties are similar to Composition B. It is used by the Japs in Torpedoes and as a booster surround.

It is unstable, reacts with metals the same as Picric Acid and is toxic.

Trinitroanisole is evidently used due to a shortage of TNT.

G. <u>German Filler</u> (use not stated) RDX/Calcium Nitrate/Ammonium Nitrate/EDD/Wax 8/5/55/30/2. This is a cast, white explosive having much the same characteristics as Amatol 50/50. Its use is indicative of material shortages.

H. <u>German Filler #109</u> - This is a gray, pressed explosive made from RDX/Aluminum/Wax 70/26/4. It is used in pellet form as a biscuit filling, with Nitroguanidine in the nose and with a surround of Trialin 106, in the 500 Kg. G.P. and the 1800 Kg. A.P. bombs. It is more sensitive than RDX itself and could not be used without the protection of Nitroguanidine (see). The 106/109 combination is also used in Pilotless Aircraft Bombs.

I. <u>Italian Bursting Charge</u> - This is a white pressed explosive consisting of RDX/Ammonium Nitrate/Wax 22/75/5 used in Shells. It would be similar to 80/20 Amatol but more sensitive. Its use indicates a TNT shortage.

J. Russian Bursting Charge - This is a yellow, cast explosive composed of 28% Tetrytol 42/58 and 72% RDX. It was reported as used in a 76 MM A.P. Shell with an incendiary nose charge of Al/Barium Nitrate/TNT/Sulphur 46/39/14.7/.3. This charge would be almost as sensitive as RDX and it is difficult to understand its use in A.P. Shells.

K. The British are supposed to have used a mixture of 60/40 RDX/DNB. This is a light yellow, cast explosive with explosive characteristics intermediate between TNT and Composition B and about as sensitive as Picric Acid. The specific use was not stated.

L. The Japs use a mixture of Ammonium Nitrate/RDX 84/16 and 78/22 in some of their bombs. It is a white pressed explosive similar to 80/20 Amatol but more sensitive (about the same as Picric Acid). RDX is substituted for TNT due to shortages.

SECTION II

PENTAERYTHRITOLTETRANITRATE BASED EXPLOSIVES

1. PENTAERYTHRITOLTETRANITRATE
$C(CH_2ONO_2)_4$

This material was patented in Germany in 1894. Although it has been used commercially since 1937 little or no use was made of it for Military purposes until this war. It is known by the following names:

PETN	United States
Penthrite	Britain
Nitropenta (NP)	Germany
Pentrit	Germany
Niperit	Uncommon
Nyperite	Uncommon
Pentryl	Uncommon

Penta	Uncommon
Niperyth	Uncommon
Penthrit	Uncommon

A. Properties:

1. PETN is white in color.

2. When used alone it is pressed as its melting point of 138°-141°C prevents casting.

3. PETN is manufactured from Formaldelyde and Acetaldehyde which are condensed in the presence of Calcium Hydroxide to Pentaerythritol, a Tetrahydroxyl Alcohol. This is nitrated to PETN. It is generally used at a density of 1.63.

4. Explosive Properties:

a. PETN is the most sensitive of the Secondary High Explosives in general use. It has a drop test figure of 6" (14" for TNT). It will always detonate from the impact of a rifle bullet and it has an ignition temperature of 172°-210°C.

b. It is one of the strongest known explosives being 66% stronger than TNT.

c. It detonates at 8300 meters per second and has a brisance figure of 61.9.

B. The use of PETN, as such, is restricted because of its sensitivity. Its primary use is for boosters and bursting charges in small caliber ammunition. Specific uses follow:

1. United States - Upper detonator in some Land Mines and Shells. It is the explosive in Primacord Detonating Fuse (Velocity 6200 M/sec.).

2. ritain - It is the explosive in Cordtex Detonating Fuse.

3. Russia - Lower detonator in the fuzes.

4. Italy - Upper detonators and boosters in small Shells. Filler in small caliber Shells (2 cm)

5. Germany - Explosive #3 - NP - Lower detonator and filler for Grenades and small Shells (2-5cm). It is indicated by green markings on ammunition boxes.

6. Japan - Upper detonator - small Shells.
Lower detonator - small Shells.
Booster - small Shells.
Filler for 50 caliber and 7.7 MM bullets.

C. PETN is not entirely stable at high temperature. At 43°C decomposition, with formation of Nitric Oxide, is autocatalytic. The presence of Dipentaerythritolhexanitrate, which is inherent in manufacture, increases stability up to a certain point and then decreases it.

D. It is somewhat acidic and tends to have a very slight reaction with Steel, Copper and Zinc.

E. It is soluble in Acetone and can be decomposed by a boiling solution of Ferrous Chloride.

F. PETN has the following advantages:

1. It is made from synthetic raw materials.

2. It is very powerful combining strength with brisance.

Its disadvantages are:

1. Its sensitivity is so great that it is difficult to desensitize it and at the same time utilize its full value.

2. Its high melting point prevents cast loading.

3. It requires five pounds of Nitric Acid to produce one pound of PETN.

Because of these disadvantages plus the fact that it requires large amounts of Methyl Alcohol (for Formaldehyde) little use was made of PETN until lately. With the need for more powerful explosives and the discovery of the process of making Methyl Alcohol synthetically, interest was aroused in PETN. Experiments are under way to utilize it in desensitized forms. To date these have taken the form of combinations with the Nitrohydrocarbons for desensitizing and casting or with waxes or oils for desensitizing and pressing.

2. PENTOLITE

This is most widely used PETN based explosive. It is also known as Pentol (German) and Pentritol.

A. Properties:

1. Pentolite is a dirty white to light buff in color. Italian Pentolite is reported as being dyed red.

2. It is usually cast loaded, melting between 80 and 90°C. Its loading density is 1.56 to 1.63.

3. Pentolite is usually a mixture of 50/50 PETN and TNT. 8% wax may be added as a desensitizer. This mixture is called Pentolite D-1. Because PETN is so sensitive it is desirable to coat the grains with TNT. To effect this result the PETN and TNT are disolved in Acetone, mixed, added to water and then precipitated out as a mixture.

4. Explosive properties:

a. Pentolite is very sensitive. It has a drop test of 9" compared with 14" for TNT. It will detonate 92% of the time from the impact of a bullet and from a temperatures of 174°-220°C.

b. It is about 30% stronger than TNT.

c. It detonates at 7500 meters per sec. and [illegible] brisance figure of 53.

B. Pentolite is used by all the warring nations, principly as a bursting charge. Specific uses are:

1. United States - Bursting Charge in small caliber Shells (e.g. 20 mm), Hollow Nose ammunition of all types (e.g. A.T. Rifle Grenade and Bazooka), Rockets and Shaped Demolition Charges. In some ammunition (e.g. Bazooka) an auxilliary booster or booster surround of 90/10 PETN/TNT is used. This is simply a slightly desensitized PETN.

2. Britain - Bursting charge in M.C. Bombs, Fragmentation Bombs, (increases velocity of fragments from 2900 to 3200 per sec. compared with TNT), Anti-personnel Mines and 40 mm Shells.

3. Italy - Bursting Charge for Land Mines ([illegible]) and Demolition Charges.

4. Germany - Filler #16-FPo2/NP10 - TNT/PETN/10% wax - Shells.

*Filler #[illegible]7-FPo2/NP10/[illegible] - TNT/PETN/10% wax plus 10% Aluminum - Shells.

Filler #28-F 10/A 10 (pressed) TNT/PETN/[illegible] wax - Shells

Filler #4[illegible] (Pentol) - Shells

Pentolite plus 10% wax - Demolition charges

Pentolite-[illegible]-booster - 47 mm Shells

*The Aluminum is not incorporated in the mixture but added for incendiary effect.

5. Japan - Bursting charge - 20 and 30 mm Shells

C. Pentolite is not entirely stable in storage. The TNT acting as a solvent for PETN accelerates the natural tendency of the PETN to decompose.

Storage at high temperatures may result in separation of the two explosives.

D. Reaction with metals - Same as PETN.

E. Pentolite is soluble in Acetone.

F. Pentolite is a very effective explosive and is 49% more efficient in shaped charges than TNT. Its high sensitivity precludes its use in ammunition which should not detonate from the shock of impact.

3. PENTAERYTHORITOLTETRANITRATE - WAX MIXTURE.

This explosive, widely used by the Germans and Italians, is an attempt to desensitize PETN for use in larger quantities. It is also known as PETN-Wax and Penthrite Wax.

A. Properties:

1. PETN/Wax is either pink (German) or Blue (Italian) due to the use of dye. Its natural color would be white.

2. It is press loaded.

3. It is manufactured from varying percentages of PETN and Lignite (Montan) Wax.

4. Explosive Properties:

a. The sensitivity varies with the amount of wax running from about the same as Tetryl (8") to about the same as TNT (11").

b. The strength is also affected by the wax varying from about 4[illegible] stronger than TNT to the same or less than [illegible].

c. The velocity and brisance are also affected in the same way varying from about 7500 meters per second and 50 as a maximum.

B. PETN-Wax is used both for a booster and bursting charge depending on the amount of wax.

Specific uses follow:

1. Germany:

Filler #32 - NP 10- PETN/Wax 90/10 (These are standard Sub-
(boosters in all types of
(ammunition
Filler #33 -NP 15- PETN/Wax 85/15 (

Filler #34 -NP 30- PETN/Wax 70/30-Filler for Special Shells.

Filler #36 -NP 40-PETN/Wax 60/40 (Fillers for Practice
(
Filler #38 -NP 65- PETN/Wax 35/65 (Shells

Filler #37 -NP 50- PETN/Wax 50/50 -Shells.

The sub-booster in the bomb Gaine is usually 92/8 PETN/Wax. 90/10 is used as a core in the S. Mine. 82/18 and 87/13 mixtures are used in small Shells.

It is the standard Burster for Chemical and Incendiary ammunition.

It is used in Hollow Nose Ammunition, Pistol and Rifle Grenades.

It is the explosive in Detonating Fuse (may be mixed with [illegible] Lead).

2. Italy: It is used as a booster and bursting charge in small Shells (e.g. 20 mm) and pressed into blocks as a Demolition Charge.

3. Japan: Used as a burster in 13 and 1[illegible] mm Incendiary Shells (white in color, probably uses Beeswax).

C. Stability - Same as PETN.

D. Reaction with Metals - Same as PETN.

E. Solubility - Same as PETN. Ammunition containing PETN/Wax should not be steamed out as the steam will melt the wax leaving pure PETN.

F. With the addition of 8-10% wax this explosive makes a powerful and sufficiently insensitive booster. The increased addition of wax, however, results in decreased efficiency. Wax is a pure hydrocarbon.

It does not enter into the detonation but it will burn from the heat of the explosion robbing the explosive of its Oxygen, decreasing the completeness of combustion and reducing the strength and the velocity of the explosive. Its use in large quantities does not indicate a utilization of PETN because of its power but rather because of a shortage of raw materials.

4. MISCELLANEOUS PENTAERYTHRITOLTETRANITRATE MIXTURES

There are a number of little used PETN mixtures which were evidently tried to utilize the power of PETN or necessitated by a shortage of raw materials.

A. Pep-3: This is an experimental demolition explosive made from 86/14 PETN/Mineral Oil. It appears to be slightly less effective than Composition C but more stable. Tests are now being conducted to determine its suitability.

B. German Filler #43 Plastic Pentrit: This is used in H.E. Shells. It is probably similar to Pep-3.

C. German Filler #45: NP 30/H - PETN/RDX 50/50 plus 30% wax. This is used in special projectiles. It is similar to PETN/Wax 70/30.

D. Italian Filler INP: Ammonium Nitrate/PETN/Wax 75/20/5 -- Used in shells. This is an Amatol type explosive using desensitized PETN instead of TNT due to a shortage in raw materials. It is similar to Amatol 80/20 in characteristics.

E. Italian Filler for 500 Kg. Time Bomb: 65/35 PETN/Pentaerythritoltetracetate. This is a brown, cast explosive as insensitive as TNT but 25% less brisant. Its use indicates a shortage of raw materials.

F. Jap filler for 7.7 MM bullets: 17/83 PETN/RDX. This filler would have the same characteristics as RDX or PETN used by themselves.

SECTION III

ETHYLENEDINITRAMINE BASED EXPLOSIVES

1. ETHYLENEDINITRAMINE
$(CH_2)_2(NH)(NO_2)_2$

Ethylenedinitramine is one of the newer explosives which have come into use during the present war. It is usually called Edna or Haleite.

A. Properties:

1. Edna is white in color.

2. Its melting point of 174°-179°C prevents cast loading.

3. An attractive feature of Edna is the fact that is is manufactured from synthetic raw materials. The ingredients are Ethyl Alcohol, Chlorine, Urea (from Ammonia and Carbon Dioxide) and Nitric Acid.

4. Explosive Properties:

a. Edna has a drop test of 10 inches and will detonate [illegible] of the time from the impact of a bullet. Its flash point is 169° to 180°C.

b. It is about 40% stronger than T.N.T.

c. It detonates at 7800 meters per second and has a brisance figure of 51.

B. Edna cannot be used by itself with safety as it is too insensitive for a booster and too sensitive for a bursting charge. It is used by the United States in the form of Ednatol.

C. Edna is stable in storage.

D. It is an acid and in the presence of moisture will react with all metals, except Aluminum and Stainless Steel, to produce sensitive salts.

E. It is soluble in water and Acetone.

F. Edna, because of its synthetic manufacture, its strength and its brisance can be expected to be one of the main explosives in the next war. Its use is limited at present because we are set up to fight the war on a TNT basis and Edna mixtures are not enough better than TNT to change over our production. The fact that it cannot be cast loaded is an additional drawback.

2. EDNATOL

Ednatol is the only form in which Edna is being used at present.

A. Properties:

1. Ednatol is a dirty white-to-buff in color.

2. It has a melting point of 80°-90°C and is cast loaded.

3. It is manufactured from 60% Edna and 40% TNT. The following combinations have also been tried experimentally:

EXPLOSIVE	% EDNA	% TNT	% OTHER INGREDIENTS
Ednatol	60	40	
Ednatol	55	45	
Ednatol	50	50	
Ednatol	60	40	+ Aluminum
APX-5A	87	--	(5 Wax (8 Aluminum
Experimental	55	27	18 Tetryl
Experimental	55	31.5	13.5 PETN
Ednatol	54	46	+8 Aluminum

The density of 60/40 is 1.62.

4. Explosive Properties:

a. Ednatol 60/40 is about as sensitive as Picric Acid. It has a drop test of 12-13" and will detonate about 17% to 20% of the time from the impact of a bullet, and at temperatures of 159°-190°C.

b. It is about 19% stronger than TNT.

c. Its detonation rate is 7400 meters per second with a brisance figure of 48.

B. It is used by the United States in 90 and 260 pound fragmentation bombs as alternative explosive.

C. Ednatol is stable in storage.

D. It will attack metals much the same as Edna but to a lesser degree.

E. It is partially soluble in water and Alcohol and very soluble in Acetone.

F. The addition of TNT reduces the sensitivity to a point where Edna can be used with safety. It also lowers the melting point for cast loading. Ednatol gives better fragmentation than TNT and is a much better explosive but it would not pay us to convert TNT production at this time.

A comparison of certain characteristics follows:

EXPLOSIVE	PEAK PRESSURE	IMPULSE	WATER SHOCK
TNT	100	100	100
Ednatol	107	110	114

SECTION IV

ETHYLENEDIAMINEDINITRATE BASED EXPLOSIVES

1. ETHYLENEDIAMINEDINITRATE

$(CH_2)_2(NH_2)_2(HNO_3)_2$

There is very little information available concerning this explosive. It is a development of the present war and used only by the Germans who called it Diamin. It is usually abbreviated to EDD.

A. Properties:

1. EDD is a white explosive and is found press loaded due to its high melting point of 185°-187°C.

2. It is manufactured from the synthetic raw materials: Ethyl Alcohol, Ammonia and Nitric Acid.

3. Explosive Properties:

There is little information regarding the properties of this explosive and that little varies widely.

a. The sensitivity is given as 20% less than Picric Acid and 50% less than TNT which would put the drop test somewhere between 15" and 21". It should be safe to assume that it will not detonate from the impact of a bullet. It decomposes at 270°C.

b. Its strength is about 14% to 28% greater than TNT.

c. No velocity or brisance figures are available except the statement that it is of low brisance.

B. It is used by the Germans by itself and in mixtures. Specific uses are:

Filler #83 - Cast in H. E. mixtures.

Filler #86 - Pressed with an RDX/Wax booster - A.P. Shells and 10 cm and 7.5 cm Shells.

C. EDD is hygroscopic and unstable.

D. Reaction with metals - No information.

E. Solubility - EDD is soluble in water.

F. From the information available this does not appear to be a very attractive explosive and is probably used by the Germans because it doesn't require any strategic raw materials.

2. ETHYLENEDIAMINEDINITRATE - AMMONIUM NITRATE MIXTURES

A. Properties:

1. These mixtures would normally be white but may be gray to brown depending on the Ammonium Nitrate.

They have a melting point of 102.5°C to 105°C which permits cast loading.

2. There are two mixtures reported:

55/45 Ammonium Nitrate/EDD

53.5/45/1.5 Ammonium Nitrate/EDD/Aluminum

The combination of Ammonium Nitrate and EDD forms an eutectic lowering the melting point for cast loading.

3. Explosive Properties:

a. The sensitivity figures for these mixtures are not available but they should be similar to EDD. They decompose at 278°C.

b. The strength is reported as 26% greater than TNT.

c. Velocity and brisance would be less than that of EDD.

B. The mixtures are used only by the Germans:

Filler #20 - EDD/NH_4NO_3/Al 45/53.5/1.5 - Use not stated

Filler #84 - EDD/NH_4NO_3 45/55 - Used in shells

German markings designating EDD are a pink container with a blue stripe.

C. These fillings would be extremely hygroscopic and unstable.

D. The reaction with metals would approximate that of Amatol.

E. They are soluble in water.

F. The mixtures are probably used to lower the melting point of EDD for cast loading.

SECTION V

MISCELLANEOUS ALIPHATIC NITRATES

1. NITROSTARCH EXPLOSIVE

Nitrostarch is nitrated corn starch used to sensitize combustibles and oxidizing agents in much the same manner that Nitroglycerin is used in dynamite.

It has always been considered a reserve explosive due to its lack of stability and its dusty and inflammable nature.

The Army has used an explosive called Trojan Explosive as a reserve demolition agent. Its properties follow:

A. Properties:

1. It is gray in color.

2. It is pressed into half pound and pound blocks at a density of 1.5.

3. It is manufactured from Nitrostarch/Sodium Nitrate/Barium Nitrate/Oil/Stabilizer. (DPA or Calcium Carbonate) 40/37.7/20/0.8/1.5)

4. Explosive Properties:

a. Trojan Explosive is rather sensitive to shock, friction and heat. It has a drop test of 8" and will detonate from the impact of a bullet 90% of the time. It is very dusty and inflammable igniting at 195°C and burning with explosive violence.

Care should be taken in using it because, under field conditions, it is difficult to disassociate shock and friction and it can ignite from friction.

b. Trojan Explosive is 96% as strong as TNT.

c. It detonates at 6100 meters per second and has a brisance figure of 37.7.

C. It is unstable in storage, being hygroscopic. This will very often make it extremely insensitive and cause misfires. On the other hand it decomposes at elevated temperatures in the presence of moisture (50°C for 354 days). This has been known to cause spontaneous detonations.

D. It corrodes Iron and Copper.

E. It is soluble in Acetone.

F. The advantage of Trojan Explosive, as a demolition agent, lies in the fact that Nitroglycerine Dynamite of the same velocity is even more sensitive.

Its disadvantages are obvious.

It is no longer being manufactured for the Government but excess stocks are being utilized for training purposes.

It is not used by any other country.

2. GUNCOTTON

A. Properties:

1. This is a white explosive.
2. It is pressed into a one-pound demolition block at a density
3. It consists of uncolloided Nitrocellulose/Moisture 87/13.
4. Explosive Properties:

a. It is abont as sensitive as TNT. (Dry, it would be about as sensitive as PETN). It ignites at 195°-200°C.

b. Its strength is about 98% of TNT. (It is 10% stronger than TNT when dry).

c. It detonates at 5500 meters per second and has a brisance of 32. (7300 and 46 dry).

B. It is used by the British as a standard demolition agent.

C. It is hygroscopic and unstable much the same as Single Base Powders. 30% moisture will prevent detonation.

D. It has no reaction with metals.

E. It is soluble in Acetone.

F. In the wet form, this is an inferior explosive. In the dry form, it is too sensitive for front line work. It is difficult to understand its use unless it is save TNT.

3. NITROGUANILINE

$O_2NNHC(NH)NH_2$

This explosive has been considered for Armor-Piercing Ammunition because it is made synthetically and is insensitive.

A. Properties:

1. Color - Yellow.

2. Form - Pressed - Melting point 230°C.

3. Manufacture - Urea and Ammonia Nitrate.

4. Explosive Properties:

a. Sensitivity - Equal to or slightly less than TNT.

b. Strength - About 82% of TNT.

c. Velocity and brisance - It detonates at about 7000 meters per second but due to the lack of gas volume its brisance is low (about 30).

B. It has a cool temperature of explosion and is used to cool smokeless powder thus reducing flash.

It is used by the Germans in the nose of their 1800 Kg. A.P. bomb to protect the filling of Trialen 109 (see) from the shock of impact.

It is also used by the Italians in two Amatol type fillings called Albite and Umbrite.

C. Nitroguanidine is unstable.

D. It has no reaction with metals.

E. It is soluble in Acetone and slightly soluble in water.

F. Nitroguanidine is an inferior explosive and is used due to a shortage of TNT.

CHAPTER 8

MISCELLANEOUS EXPLOSIVES

SECTION I

DYNAMITES

Dynamites have been the chief commercial blasting explosive for years. They have little Military application, except for demolition purposes, because of their sensitivity.

A. Properties:

1. Dynamites are usually brownish in color.

2. In form they may be either a powder or a plastic putty-like material.

3. The two types in general military use are 50% Nitroglycerine Dynamite and Gelignites. The dynamite is manufactured by sensitizing Sodium Nitrate and wood meal with 50% nitroglycerine. The Gelignites are the same except for the addition of 2 to 7% Collodion Cotton to form a gelatin with the Nitroglycerine.

4. Explosive Properties:

a. These explosives are all very sensitive to shock, friction and heat and will definitely detonate from the impact of a bullet unless they are desensitized by addition of inert materials which in turn would reduce explosive power. When frozen they become extremely sensitive due to segregation of the Nitroglycerine. For the same reason they are less efficient and may give a low order detonation.

b. They are approximately equal to TNT in strength.

c. In velocity and brisance they are inferior to TNT, having a rate of detonation of about 6000 meters per second and a brisance figure of about 35.

B. The United States Engineers use 50% dynamite for demolitions in this country. The British use Gelignites under the names of Nobel's 803,808,823,851 and Saxonite in Anti-Tank mines, in the Stickey Grenade and for Demolitions. Italy and Germany are reported as using Gelignites for a variety of purposes particularly Grenades.

C. These explosives are considered unstable due to the hygroscopicity of certain ingredients and the tendency of Nitroglycerine to segregate after prolonged storage. If the bottom of the container is moist, great care must be exercised until it has been determined whether the Nitroglycerine has leaked.

D. Nitroglycerine may be neutralized by a Sodium Sulphite- [illegible] solution. It is soluble in Acetone and Alcohol and can be destroyed by boiling in Alcohol or Sodium or Potassium [illegible]

Nitroglycerine Dynamites may also be destroyed by burning but proper safeguards must be taken as the explosive can detonate.

E. Dynamites are used for military purposes primarily for their economy. Also they do not require a booster and are very sensitive to detonation by propogation. Their main disadvantages are their sensitivity and lack of stability.

The British use one Pound of Gelignite to detonate bombs up to 250 Kg. and five pounds for bombs over 250 Kg.

SECTION II

CHLORATE AND PERCHLORATE EXPLOSIVES

There have been a number of these explosives used on a small scale in this war. The chief thing to remember about them is that they are all very sensitive, the Chlorates being somewhat more so than the Perchlorates.

1. JAPANESE TYPE 88 EXPLOSIVE

This explosive is also called Haensosanbakuyaku.

A. Properties:

1. Color - Gray.

2. Form - Pressed.

3. Manufacture - Ammonium Perchlorate/Ferro Silicon/Wood Meal/ Crude Petroleum 75/16/6/3.

4. Explosive Properties:

a. It has a drop test of about 7" - 8".

b. It is about 70% stronger than TNT.

c. It detonates at 4200 meters per second and has a brisance figure of about 30.

B. It is used by the Japs in Mines. They also have a variation of this explosive, used in a high explosive Anti-aircraft Missile, consisting of Potassium Perchlorate/Sulphur/Aluminum/Antimony Sulfide 55.7/16.7/14.6/13. It has much the same characteristics as Type 88.

C. Type 88 Explosive is hygroscopic and unstable.

D. I will react with metals much the same as Ammonium Nitrate.

E. It is soluble in water, Alcohol and Acetone.

F. It is a cheap, strong, underwater exploive but would seem to be too sensitive for the use to which it is put. Also, it is lacking in brisance.

2. ITALIAN CHEDDITES

In the past there have been a number of different Chlorate or Perchlorate explosives called Cheddites. They usually consisted of combustibles sensitized by Potassium, Sodium or Ammonium Chlorate or Perchlorate, and bound together with vaseline or paraffin.

Their two common characteristics were their sensitivity and lack of stability.

The Italians have used these in Land Mines in this war under the names of Romite and Cheddite. They will usually be brownish or grayish plastic explosives. They are definitely inferior to dynamite in explosive characteristics.

SECTION III

LIQUID EXPLOSIVES

Periodically, during this war, there have been reports of a new super-explosive many times more powerful than the standard explosives. Such reports should be taken with at least one grain of salt.

Fundamentally, explosives react by changing from a solid to a gas, many times the original volume. This gas is formed by oxidizing Carbon and Hydrogen to Carbon Dioxide and Steam. Maximum expansion takes place when this oxidation is complete, as in Nitroglycerine which is 60% stronger than TNT. It would seem impossible to beat this figure by more than a few percent unless we begin to utilize atomic energy.

The following is a list of proposed explosives comparing them to Picric Acid in strength and sensitivity:

EXPLOSIVE	STRENGTH	SENSITIVITY
	PA = 100	PA = 100
Picric Acid	100	100
Methyl Nitrate	174	29
Ethyl Nitrate	128	--
Ethylene Glycol Dinitrate	170	13 plus
Diethylene " "	130	127
Nitroglycerine	160	13
Chlorhydrindinitrate	125	120 plus
Nitromethane	127	100
Anilite (Nitrogen Peroxide/Butane)	161	Sensitive
Dithekite (Nitric Acid/Nitrobenzene/Water)	110	100
Liquid Oxygen/Lampblack	100	50

The following objections apply to this type of explosive:

1. Most of them are too sensitive for military use.

2. Some, such as Anilite, have to have their components in separate compartments with the mixing taking place just before detonation.

3. Some, such as Liquid Oxygen and Solid Acetylene, have to be used immediately after manufacture otherwise they evaporate and lose strength. If sealed in a container the evaporation would tend to burst the container endangering the plane.

4. While some are stronger than standard explosives, this advantage is lost due to low density.

Therefore, it is safe to assume that since liquid Explosives present too many problems and too few, if any, advantages, they will not be used unless it be to circumvent material shortages and if they are used, there is nothing to be excited about.

CHAPTER 9

TOXICITY OF EXPLOSIVES

Practically all explosives are more or less toxic. This is particularly true of the Aromatic Nitrocompounds. In addition to being toxic most of these will also stain the skin yellow.

The toxic effect is usually produced, at least as far as B.D. Personnel are concerned, by absorption through the pores of the skin.

The degree of toxicity, to any individual, will depend on the degree of allergy of that individual and his length of exposure to any particular explosive.

This fact, together with the wide use of mixtures in this war, should cause everyone to take all due precautions in handling explosives unless they are absolutely sure what explosive they are handling and its effect on them personnally.

The following is a list of explosives, which are known to be toxic, and their effects on personnel:

1. Lead Azide and Nitroglycerine will relax the arteries. The heart beat is stepped up to compensate for this, resulting in severe headaches. This effect is not dangerous or permanent but it may distress to the point of incapacitating.

2. Mercury Fulminate may cause infection from contact with cuts.

3. TNT is extremely toxic and may cause:

   (a) Dermatitis or skin irritation.

   (b) Irritation of the alimentary tract.

   (c) Cyanosis or the reduction of the oxygen carrying ability of the blood.

   (d) A form of Jaundice.

(e) Aplastic anemia or the destruction of the marrow of the bones.

(f) Staining of the skin and hair.

All these effects are caused by absorption through the skin which is made easier by heat and humidity. Symptons are breathlessness, headaches, dizziness, dullness, weakness, constipation, vomiting, a livid face and blue finger tips. The urine is light brown to red to coffee colored.

4. TNT exudate is more toxic than TNT itself.

5. Composition C2 and C3 have the same effect as TNT.

6. Dinitrotoluene has much the same effect as TNT.

7. Dritrobenzene has an effect similar to that of TNT but is also absorbed thru the lungs and digestive tract and may affect the vision, the heart action and nerve reflexes.

8. Dinitrochlorobenzene and Trinitrochlorobenzene are more toxic than Dinitrobenzene.

Phosgene may be produced from low order detonation.

9. Dintrophenol is about the same as P.A.

10. Picric Acid has the same tendencies as TNT but is not as severely toxic.

11. Tetryl has the same toxic effects as TNT but is more severely toxic especially to the skin. It causes a dermatitis similar to poison Ivy. It can be absorbed by inhalation.

12. HND causes severe blisters resembling burns and its dust is injurious to the mucuous membranes of the mouth, nose and lungs in addition to its other effects similar to those of TNT.

13. Trinitroanisole is similar to Picric Acid in general toxicity but is more severely toxic to the skin.

In order to prevent explosive poisoning the following precautions should be taken:

1. Do not expose the skin to explosives. Wear gloves under all conditions and when working with explosives over a period of time, keep the arms, legs and torso covered. When steaming out a bomb wear boots.

2. Keep the person and clothes clean at all times. Wash the hands thoroughly after handling explosives and do not permit clothes to become saturated. They should be washed before reuse.

When handling explosives over a period of time the hands should be washed at frequent intervals to prevent absorption through the pores. The hands should always be washed before touching the face, rubbing the eyes, eating or using the latrine.

A solution of one teaspoonful of Sodium Bicarbonate per pint of warm water is effective in combating acidity.

A special soap, consisting of 25/25/50 Triethanolamine/Industrial Ethanol/Commercial Liquid Soap, will disolve the Aromatic Compounds and give off a violet color as long as they remain on the skin.

After washing the following cream may be applied: It has been found effective in preventing irritation:

INGREDIENTS	QUANTITIES
Water	750 C.C.
Borax	50 Grams
Sodium Carborate	2 Grams
Glycerine	72 C.C.
Stearic Acid	130 Grams
Gum Tragacanth	4 Grams
Sodium Perborate	100 Grams
Oil of Lavender	4 Drops

This mixture will make 1 Kg. of cream. The chemicals used are the U.S.P. grade. To prepare, place the water, borax, Sodium Carbonate and Glycerine in an enamel dish on a hot water bath and stir. When all the solids have disolved and the solution is hot, add Stearic Acid and stir occasionally. When the Stearic Acid has all reacted and the mixture is free from lumps, add the Gum Tragacanth and Oil of Lavender and stir vigorously with a large spatula. Allow the mixture to cool with continuous, or nearly continuous, stirring until cold. Then add Sodium Perborate and continue stirring until a uniform non-gritty mixture is obtained. Do not add the Perborate while the cream is still warm.

The cream should be used as fresh as possible, but can be stored for a limited period in a refrigerator.

3. As a final precaution, Medical attention must be obtained whenever any skin irritation or discoloration is noticed.

CHAPTER 10

FIELD TESTING OF EXPLOSIVES

In the field it is often necessary to identify the various explosive components of ammunition before inerting the ammunition. It is possible to do this by an application of the individual's knowledge of the following characteristics.

1. Color - It will be noticed that many explosives are various shades of yellow so that color observation is not reliable. However, after practice, it is possible to become familiar with the appearance of explosives and, if positive identification is not always possible, at least color observation can be used to eliminate possibilities and narrow the range down to a few explosives.

2. Use of the Explosive - If the functional and tactical use of the explosive are considered, in conjunction with the color, the range can be narrowed down even more and the identity of the explosive established at least within the range of sensitivities. For example, if a white explosive is used by the Japs as a booster, the natural conclusion would be that the explosive is PETN or RDX. Further identification is not necessary, from a safety standpoint, if the explosive is assumed to be PETN and treated accordingly.

3. Melting Points - If it were desirable to positively identify the explosive this could be done by determining the melting point.

In order to carry out this test, powder a very small quantity of the explosive and put it into a test tube or a reasonable facsimile thereof. A thermometer is clamped to the tube so that the base of the tube and the base of the thermometer are on the same plane and both are inserted into a bath of light oil which is heated rapidly. The melting point of the explosive is observed and taken as the approximate range.

After the oil cools and the explosive solidifies, the bath is again heated to within 5° of the range. Heating is stopped and then resumed slowly, raising the temperature 10° per minute until the explosive begins to melt.

Heating is stopped. If melting is completed without raising the temperature, the explosive is pure and not a mixture and the temperature can be considered as the melting point.

If the explosive does not melt completely, raise the temperature 1° at a time and repeat until the explosive does melt. If heat is added more than three times, the explosive is a mixture.

The temperatures at which the explosive begins to melt and at which melting is completed, are recorded as the melting range of the explosive. In this way the components of mixtures can be identified.

This test is not used for Primary High Explosives.

4. Sensitivity - In order to determine the sensitivity of an unknown explosive, to ascertain how carefully it must be treated, the following tests can be conducted.

a. Powder a very small quantity of the explosive, place it on a hard surface and hit it a light blow with a hammer. If it detonates it can be considered in the Primary Explosive range and should be treated accordingly.

b. Powder a small quantity of explosive and place the end of a length of safety fuse in the explosive. Ignite the fuse and move to a safe distance. If the explosive detonates, from the spit of flame from the safety fuse, it should be considered a Primary Explosive.

These tests should only be conducted with a very small pinch of explosive and the explosive should not be confined in such a way that fragmentation of the container can result.

CHAPTER 11

COMPARATIVE BOMB HIGH EXPLOSIVE TRAINS

In a preceding part of this pamphlet we discussed the principle of the Explosive Train. This section will discuss the application of that principle and compare characteristic Bomb High Explosive Trains of the several warring nations.

SECTION I

COMPONENTS OF A TYPICAL TRAIN

1. The Primer - There are three types of Primers in general use:

a. The Percussion Primer which consists of a sensitive composition detonated by a blunt firing pin which pinches the primer between the firing pin and an anvil. This type is generally used to ignite delays.

b. The Stab Action Primer or Friction Primer which consist of a sensitive composition designed to detonate from the stab action of a needle pointed firing pin. This type is used for both instantaneous and delay action.

c. The Ignition Primer - A sensitive composition designed to ignite from a hot wire. This type is used principally by Germany.

2. The Delay consists of a slow burning composition, usually Black Powder, designed to interrupt the detonation and permit the bomb to penetrate.

3. The Relay is usually a flash Pellet of Black Powder designed to pick up and intensify the flame, from the delay or primer, which has lost its intensity due to distance of travel. The delay and relay are not used in instantaneous fuzes but the relay is usually encountered where there is a choice between instantaneous and short delay.

4. The Detonator is a pellet of highly sensitive material which will readily detonate from flame with sufficient violence to detonate the booster. Its length is more important than its diameter as it must attain a minimum velocity of detonation. For example, in a number six Blasting Cap 5-1/2 grains of Mercury Fulminate are used to detonate Tetryl while in a fuze 19 grains are used with no more efficiency. The height of the charge is the same in both cases but the diameter is different.

5. The booster is intermediate in sensitivity. It will readily detonate from the action of the detonator and develop enough energy to detonate any of our bursting charges. The booster is always used, even when the detonator will detonate the bursting charge, to eliminate large quantities of very sensitive explosive. Here again the height of the charge is the controlling factor and in actual practice it is usual to have a sub-booster and booster to be sure that the booster will have enough length to attain a maximum velocity of detonation.

The booster is more effective at the end of the detonator due to the directional force of the detonation. Eight grains of explosive at the end of the detonator is as effective as thirty grains placed in a ring around the detonator.

It is not necessary to increase the size of the booster as the size of the bomb increases, as a certain minimum amount of booster is necessary for each explosive. In actual practice, however, an excess amount of booster is used in case the explosive has deteriorated. In many cases an auxiliary booster is used to insure a high order of detonation for very insensitive explosives or to [illegible] in case the bomb breaks up on impact.

SECTION II

UNITED STATES BOMB HIGH EXPLOSIVE TRAIN.

The United States uses Mechanical Impact Fuzes depending on the action of the Firing Pin to initiate the action of the train.

1. The Percussion type Primer, designed to produce a maximum flame, is a Mercury Fulminate composition consisting of Mercury Fulminate, Potassium Chlorate, Antimony Sulfide and frequently an abrasive such as ground glass or Carborundum. This is designed for delay action fuzes and is used with a blunt firing pin.

For instantaneous action a Lead Azide Primer Composition, sensitized with Lead Styphnate, is used with a needle type Firing Pin.

2. The delay element is Black Powder and is ignited by the flame from the Percussion Primer. In Dive Bombing, a Barium Chromate delay is used.

3. Since the Detonator is enclosed in an Aluminum case and may not be in close contact with the delay, a Relay is necessary to intensify the flame from the Delay, or from the Primer if the Delay is by-passed. This consists of a cup of Lead Azide covered with an onion skin. This ignites from the flame of the Primer or Delay and detonates with sufficient power to detonate the enclosed Detonator.

4. The Detonator is in two parts, an upper and lower Detonator. The Upper Detonator is Lead Azide sensitized by Lead Styphnate and the Lower Detonator (sub-booster) is Tetryl. The Relay detonates the Upper Detonator and the action is intensified by the Lower Detonator which will in turn detonate the Booster.

For Instantaneous Fuzes the Primer and Upper and Lower Detonators are enclosed in a Primer Detonator.

5. **The Tetryl Booster is simply a larger amount of Tetryl used to provide a margin of safety in operations.** In effect it permits attainment of **maximum** velocity by lengthening the explosive column.

6. **The Bursting Charge** may be one of the following: TNT, **Amatol, Explosive D, Composition** B, DBX, Torpex, or Ednatol.

SECTION III

THE BRITISH BOMB HIGH EXPLOSIVE TRAIN

British Fuzes operate on the same principle as ours so their Explosive Train is the same in principle.

1. The Primer may be Lead Azide or Mercury Fulminate Composition.

2. The Delay is made of Safety Fuse.

3. The Relay is Black Powder since the Detonator is in direct conatct with the Relay.

4. The Detonator is either Lead Azide, sensitized with Lead Styphnate, or 80/20 Mercury Fulminate/Potassium Chlorate.

All the above components are enclosed in a tube, similar to a Blasting Cap, which the British call their Detonator. For instantaneous action, the Delay and Relay may be eliminated. The tube is inserted in the Booster.

5. The Booster, which the British call their Exploder, consists of Tetryl or a combination of Tetryl and Pressed TNT.

6. The Bursting Charge may be one of the following: TNT, Amatol, Minol II, Baratol Cyclotol, DBX, Amatex, Pentolite, Torpex, Shellite or Tritonal.

SECTION IV

THE ITALIAN BOMB HIGH EXPLOSIVE TRAIN

This train functions on the same general principle as the others. Slight variations are present because the holders for the various components are open at either end.

1. The Primer is Mercury Fulminate composition.

2. The Delay is Black Powder.

3. The Relay is also Black Powder as there is a flash channel into the Detonator.

4. The Detonator is Lead Azide sensitized with Lead Styphnate.

5. The Sub-booster is RDX.

6. The main booster is Pressed TNT. This is evidently used due to the expense of Tetryl but it is difficult to understand why a desensitized RDX booster is not used as it would be much more efficient than TNT.

7. The Bursting Charge is generally TNT, Amatol, Ammonal or Cyclotol.

SECTION V

THE JAPANESE BOMB HIGH EXPLOSIVE TRAIN

This train is very similar to the Italian in that most of the metal holders are open at both ends.

1. The Primer is always Mercury Fulminate Composition with an abrasive. The Firing Pin is generally the needle type.

2. The Delay is Black Powder.

3. The Relay is also black Powder, the detonator being in an open container.

4. The Detonator is generally Lead Azide. Reports have indicated the use of Mercury Fulminate in Army Bombs but this has not been confirmed.

5. The Sub-booster is usually Tetryl.

6. The Booster is generally pressed Picric Acid although it may be RDX in smaller bombs. This is evidently an economy measure as Picric Acid is not as effective as Tetryl.

7. The Japs frequently use an Auxiliary Booster of Pressed Type 98 Explosive in the tail of their larger bombs.

8. The Bursting Charge may be one of the following:

Pressed or Cast Picric Acid, Trinitroanisole, Type 98 Explosive, Cyclotol or the TNT/Picric Acid Mixture.

SECTION VI

THE GERMAN BOMB HIGH EXPLOSIVE TRAIN

The German Train is somewhat different than the others in that the German Fuzes are electrical and depend on ignition, from a hot bridge wire, to initiate the train.

1. The Primer consists of a silver Bridge Wire on which is beaded a paste of Lead Styphnate, Collodiom Cotton and Amyl Acetate. This is ignited when the bridge wire becomes red hot. The Lead Styphnate mixture has a surround of 80/20 Potassium Nitrate and Charcoal to increase the flame.

2. The Delays vary. For Delays up to one second Black Powder is used. For Delays of five to fourteen seconds a Delay of the following type is used:

a. An Ignition Mixture of:

5% Nitrocellulose
75% Red Lead
20% Carborundum

b. A Delay of:

10% Potassium Perchlorate
50% Lead Chromate
40% Antimony

c. A Booster of:

6% Resin
56% Potassium Perchlorate
38% Lead Ferrocyanide

The Ignition Mixture facilitates the ignition of the insensitive Delay and the Booster intensifies the flame.

For Delays up to 40 seconds, the following type of delay is used:

a. An Ignition Mixture of:

5% Nitrocellulose
75% Red Lead
20% Carborundum

b. A Delay of:

0.4% Potassium Chromate
78.0% Barium Chromate
21.0% Zirconium
0.1% Wax
0.5% Nitrocellulose

c. A Booster of:

5% Nitrocellulose
75% Red Lead
20% Carborundum

3. The Relay may be Black Powder or:

25-40% Potassium Perchlorate
40-50% Lead Sulphocyanate
4-8% Sulphur
20% Nitrocellulose

4. The Detonator is Lead Azide sensitized by Lead Styphnate.

5. The Sub-booster is a layer of PETN over PETN Wax. Both of these components are contained in a cup called a Gaine which corresponds to our detonator.

6. The Gaine is surrounded by a pressed Picric Acid Ring with the remainder of the Fuze Pocket filled with pressed Picric Acid Pellets. These act as a Booster.

7. Practically all German Bombs have an auxiliary booster of Pressed TNT Pellets which gives a margin of safety in operation and permits the use of low grade explosives.

8. The following bursting charges may be used: TNT, TNT Wax, Amatol, Ammonal, Cyclotol, Hexamit or Tornex. There are a great many miscellaneous explosives, which may be used for special purposes, in addition to these.