APPENDIX A-3. EXPLOSIVES: NATURE, USE, EFFECTS, AND APPLICATIONS

The purpose of this appendix is to provide a general understanding of the nature of explosions and explosives. It is intended not as a textbook or technical manual, but as a source of background information for police, security, and other law enforcement officials finding themselves involved in the prevention and control of the illegal use of explosives.

EXPLOSIONS

TYPES OF EXPLOSIONS

An explosion can be broadly defined as the sudden and rapid escape of gases from a confined space accompanied by high temperatures, violent shock, and loud noise. The generation and violent escape of gases is the primary criterion of an explosion and is present in each of the three basic types of explosions: 1) mechanical, 2) chemical, and 3) atomic.

Mechanical Explosion

The mechanical explosion is illustrated by the gradual buildup of pressure in a steam boiler or pressure cooker. As heat is applied to the water inside the boiler, steam, a form of gas, is generated. If the boiler or pressure cooker is not equipped with some type of safety valve, the mounting steam pressure will eventually reach a point when it will overcome the structural or material resistance of its container and an explosion will occur. Such a mechanical explosion would be accompanied by high temperatures, a rapid escape of gases (steam), and a loud noise.

Chemical Explosion

A chemical explosion is caused by the extremely rapid conversion of a solid or liquid explosive compound into gases having a much greater volume than the substances from which they were generated. When a block of explosive detonates, the produced gases will expand into a volume 10,000 to 15,000 times greater than the original volume of the explosive. The expansion of these generated gases is very rapid, reaching velocities of approximately 8.05 km (5 miles) per second. Temperatures generated by the conversion of a solid into a gas state may reach 3000 °C to 4000 °C. The entire conversion process takes only microseconds and is accompanied by shock and loud noise.

Atomic Explosion

An atomic explosion may be induced either by fission, the splitting of the nuclei of atoms, or fusion, the joining together under great force of the nuclei of atoms. During nuclear fission or fusion, a tremendous release of energy, heat, gas, and shock takes place. The atomic bombs dropped on Japan in World War II were rated as equivalent to 18,140 t (20,000 tons (20 kT), or 18.18 million kg (40 million pounds), of TNT in explosive power, yet the amount of fissionable material required to produce this energy weighed approximately 1 kg (2.2 lb). With today's technology, even greater yields are possible with smaller amounts of fissionable material.

NATURE OF CHEMICAL EXPLOSIONS

The explosives normally encountered by law enforcement personnel are chemical in nature and result in chemical explosions. In all chemical explosions, the changes which occur are the result of combustion or burning. Combustion of any type produces several well-known effects: heat, light, and release of gases. The burning of a log and the detonation of a stick of dynamite are similar because each changes its form and, in so doing, produces certain effects through combustion. The real difference between the burning of the log and the detonation of the dynamite is in the time duration of the combustion process.

Deflagration (Rapid Combustion)

An example of deflagration or rapid combustion is illustrated by the internal combustion automobile engine. Inside the cylinder of the engine, combustible fuel (gasoline) is mixed with a combustion supporter (air), and the mixture is raised close to its ignition temperature by compression. When a flame from the spark plug ignites the mixture, rapid combustion or deflagration occurs. Deflagration is merely a rapid form of combustion, and ordinary combustion is simply a slow form of deflagration. The speed of the burning action constitutes the difference between combustion, deflagration, and detonation.

Detonation (Instantaneous Combustion)

Detonation can be defined as “instantaneous combustion”. However, even in detonation, the most apid form of combustion, there must be some time interval in order that the combustion action can be transferred from one particle of the explosive compound to the next. Therefore, there cannot be “instantaneous” combustion, but the extreme rapidity of the process, as compared to that of ordinary combustion and explosion, warrants the use of the term.

The velocity of this “instantaneous combustion” has been measured for most explosives and is referred to as the detonation velocity of the explosive. Detonation velocities of high explosives range from approximately 2,743 m/s (9,000 ft/s) to over 8,382 m/s (27,500 ft/s). As an illustration of detonation velocity, if a 8.05 km (5 mile) 80,467 m (26,400 ft) length of garden hose were filled with RDX (detonation velocity 8,382 m/s (27,500 ft/s)) and initiated at one end, the detonation would reach the other end of the 8.05 km (5 mile) long hose in less than 1 s.

A high-order detonation is a complete detonation of the explosive at its highest possible velocity. A low-order detonation is either incomplete detonation or complete detonation at lower than maximum velocity. Low-order detonations may be caused by any one or a combination of the following factors: 1) initiator (blasting cap) of inadequate power, 2) deterioration of the explosive, 3) poor contact between the initiator and the explosive, and 4) lack of continuity in the explosive (air space).

EFFECTS OF AN EXPLOSION

When an explosive is detonated, the block or stick of chemical explosive material is instantaneously converted from a solid into a rapidly expanding mass of gases. The detonation of the explosive will produce three primary effects and several associated secondary effects which create great damage in the area surrounding the explosion. The three primary effects produced are blast pressure, fragmentation, and incendiary or thermal effects.

Blast Pressure Effect
When an explosive charge is detonated, very hot, expanding gases are formed in a period of approximately 1/10,000 of a second (100 μs). These gases exert pressures of about 635 metric ton (700 tons) per square inch on the atmosphere surrounding the point of detonation and rush away from the point of detonation at velocities of up to 11,265 km (7,000 mph), compressing the surrounding air. This mass of expanding gas rolls outward in a circular pattern from the point of detonation like a giant wave, weighing tons, smashing and shattering any object in its path. The further the pressure wave travels from the point of detonation, the less power it possesses until, at a great distance from its creation, it dwindles to nothing. This wave of pressure is usually called the blast pressure wave.

The blast pressure wave has two distinct phases which will exert two different types of pressures on any object in its path. These phases are the positive pressure phase and the negative or suction phase. The negative phase is less powerful, but lasts three times as long as the positive phase. The entire blast pressure wave, because of its two distinct phases, actually delivers a one-two punch to any object in its path. The blast pressure effect is the most powerful and destructive of the explosive effects produced by the detonation of high explosives.

Secondary Blast Pressure Effects: Reflection, Focusing, and Shielding of the Pressure Wave. Blast pressure waves, like sound or light waves, will bounce off reflective surfaces. This reflection may cause either a scattering or a focusing of the wave. A blast pressure wave will lose its power and velocity quickly when the detonation takes place in the open. For example, assume that a block of explosive is detonated in the open, and the blast wave dissipates at a distance of 30.48 m (100 ft) from the point of detonation. If the same charge had been placed inside a large diameter sewer pipe or a long hallway and detonated, the blast pressure wave would have been still measurable at 6.096 m (200 ft) or more. This is due to the reflection of the blast wave off the surfaces surrounding it, and the reflected wave may actually reinforce the original wave by overlapping it in some places.

Since the reflected wave is a pressure wave, it will exert physical pressure. Similarly, a blast pressure wave may be focused when it strikes a surface which acts as a parabolic reflector just as sound waves can be focused and directed.

Shielding occurs when the blast pressure wave strikes an immovable object in its path. If a square, solid concrete post 60.96 cm (2 ft) thick is placed in the path of the blast pressure wave and a wine glass is placed behind this post, the blast pressure wave will strike the post, and the post will, in effect, cut a hole in the pressure wave, leaving the wine glass undamaged.

When dealing with detonations which have taken place inside buildings, many unusual effects due to reflection or shielding will be noted. These effects account for such strange things as the entire wall of the structure being blown out, but a mirror on the opposite wall remaining intact.

Secondary Blast Pressure Effects: Earth and Water Shock. When an explosive charge is buried in the earth or placed underwater and detonated, the same violent expansion of gases, heat, shock, and loud noise results. Since earth is more difficult to compress than air, and water is not compressible at all, the detonation will seem less violent. Nevertheless, the energy released is exactly the same as would result from a detonation in the open air. The effect of this violence is, however, manifested in a different manner. The blast wave is transmitted through the earth or water in the form of a shock wave, which is comparable to a short, sharp, powerful earthquake. This shock wave will pass through earth and water just as it does through air, and when it strikes an object such as a building foundation, the shock wave will, if of sufficient strength, damage that structure much as an earthquake would. An explosive charge detonated underwater will produce damage at greater distances because, unlike earth, water is not compressible and cannot absorb energy. As a result, it transmits the shock wave much faster and farther, and consequently produces greater damage within a larger area.

Fragmentation Effect

A simple fragmentation bomb is composed of an explosive placed inside a length of pipe which has the end caps screwed into place. When the explosive is detonated not only will the blast pressure effect produce damage, but shattered fragments of the pipe will be hurled outward from the point of detonation at great velocity. The average fragment produced by the detonation of a bomb will reach the approximate velocity of a military rifle bullet 822.96 m/s (2,700 ft/s) a few feet from the point of detonation. These bomb fragments will travel in a straight line of flight until they lose velocity and fall to earth or strike an object and either ricochet or become imbedded.

When an encased explosive such as a pipe bomb detonates, the rapidly expanding gases produced by the explosion cause the casing to enlarge to about one and one-half times its original diameter (material dependent) before it ruptures and breaks into fragments. Approximately, half the total energy released by the explosion is expended in rupturing the case and propelling the broken pieces of the casing outward in the form of fragments. Fragments resulting from the detonation of a high-explosive filler have a stretched, torn, and thinned configuration due to the tremendous heat and pressure produced by the explosion. In contrast, the detonation of a pipe bomb containing black powder, a low explosive, would produce fragments that are larger in size than those resulting from a high-explosive detonation, and they would not have a stretched and thinned configuration.

Precut or preformed objects such as nails, ball bearings, or fence staples, which are placed either inside the bomb or attached on the outside are referred to as shrapnel. Shrapnel serves the same purpose and has the same effect on personnel, material, and structures as fragmentation. One advantage of using shrapnel is that part of the energy released by the explosion, which would normally have been expended in fracturing the bomb casing into fragments, is used instead in propelling the preformed, separate pieces of shrapnel. Consequently, the use of shrapnel inside or attached outside a bomb results in an increase in blast damage by cutting, slicing, or punching holes in materials near the detonation point.

Incendiary Thermal Effect

The incendiary thermal effect produced by the detonation of a high or low explosive varies greatly from one explosive to another. In general, a low explosive will produce a longer time period of incendiary thermal effect than will a high explosive. A high explosive will, on the other hand, produce much higher temperatures. In either case, the duration of the effect is measured in fractions of seconds. The incendiary thermal effect is usually seen as a bright flash or fireball at the instant of detonation. If a high-explosive charge is placed on a section of earth covered by dry grass and then detonated, only a vacant patch of scorched earth will remain. However, if a low-explosive charge is placed on the same type of earth and detonated, more than likely a grass fire will result.

Unless highly combustible materials are involved, the thermal effect plays an insignificant part in an explosion. Should combustible materials be present and a fire started, the debris resulting from the explosion may provide additional fuel and contribute to spreading the fire. When fires are started inside a structure which has been bombed, they usually are traceable to broken and shorted electrical circuits and ruptured natural gas lines rather than to incendiary thermal effects. Incendiary thermal effects are generally the least damaging of the three primary detonation effects.

COMPOSITION AND BEHAVIOR OF CHEMICAL EXPLOSIVES

An explosive is a chemically unstable material which produces an explosion or detonation by means of a very rapid, self-propagating transformation of the material into more stable substances, always with the liberation of heat and with the formation of gases. Shock and loud noise accompany this transformation.

The primary requisite of a chemical explosive is that it contains enough oxygen to initiate and maintain extremely rapid combustion. Since an adequate supply cannot be drawn from the air, a source of oxygen must be incorporated into the combustible elements of the explosive, or added by including other substances in the mixture. These sources of oxygen are called oxidizers.

Explosive Mixtures

In the case of deflagrating substances, as contrasted to detonating substances, the combustible and oxidizer are blended mechanically. The result of this type of blending is known as an explosive mixture. Mechanical blending is generally used when manufacturing low explosives or propellants such as pistol and rifle powders. Propellants are materials that burn to produce gases used to perform mechanical work, such as propelling a projectile or pushing a piston. In some cases, a bonding agent such as water is added to the mixture to form a paste. When dry, the paste mixture is broken into pieces and ground to produce a finer mixture than would result from simply blending the separate ingredients.

Explosive Compounds

The first requirement of a detonating substance is that the bond between the combustible and the oxidizer must be as close as possible. Since mechanical mixing does not provide a close enough relationship, detonating explosives must be chemically blended. For example, in creating the chemical compound nitroglycerin, glycerin is poured slowly into nitric acid forming a new compound whose elements are bound tightly together. All high explosives, in contrast to low explosives, are composed of chemical compounds consisting of tightly bonded combustibles and oxidizers.

Classification by Velocity

The classification of explosives by the velocity of explosion or detonation is a convenient and widely used system for distinguishing between two major groups of explosives.

Low Explosives. Those explosives known as low explosives have rates of detonation below 999.7 m/s (3,280 ft/s). For example, black powder has a rate of approximately 399.9 m/s (1,312 ft/s). Low explosives are used primarily as propellants, because a mechanically mixed explosive charge minimizes the danger of bursting the weapon in which it is used. In a mechanical mixture the burning is transmitted from one grain of low explosive to the next, and

the gases produced build up as the powder burns. This causes low explosives, in terms of performing work, to exert a rapid pushing effect rather than a shattering effect as do high explosives. Low-explosives are used in blasting operations and are also frequently the filler for homemade pipe bombs.

A bomb using low explosives is made by confining pistol, rifle, or black powder in a length of pipe with end caps. When the confined powder is ignited, the rapidly produced and confined gases will create increasing internal pressures until the pipe container bursts and is torn apart by the pressure. Unlike high explosives, low explosives may be started on the combustion path by the application of a simple flame or acid/flame reaction and do not require the shock of a detonating blasting cap.

High Explosives. This type of explosive is designed to shatter and destroy. The detonation rate of high explosives is above 999.7 m/s (3,280 ft/s). There is a wide range in the detonation velocities of high explosives, extending from some dynamites at 2,743.2 m/s (9,000 ft/s) up to RDX at 8,382 m/s (27,500 ft/s).

High explosives differ from low explosives in that they must, in general, be initiated by the shock of a blasting cap. When low explosives begin their combustion, the burning travels from particle to particle because of the granular form of the explosive. This results in the deflagration of the material. High explosives detonate, which has been described as instantaneous combustion. When a blasting cap is detonated in a stick or block of high explosive, it delivers an extremely sharp shock to the explosive. This shock breaks the bonds of the molecules of the chemically bonded explosive material and oxidizers. The disruption of the molecules is transmitted as a shock wave radiating outward in all directions from the point of initiation. This internal shock wave is known as a detonation wave, and it causes each molecule it strikes to rupture. The rupture of each molecule causes the wave to move faster until, in a very short time and distance, the explosive material is detonating at its maximum rate. When a high explosive detonates, the speed at which the detonation wave progresses through the explosive is called the detonation velocity. It is usually expressed in feet or meters per second.

Applications of Explosives

The varying velocities of explosives have a direct relationship to the types of work they can perform. The differences in velocity determine the type of power exerted by high or low explosives. Low explosives have pushing or heaving power and high explosives have, because of the rapid expansion of their gases, shattering power. Thus, an expert in the use of explosives will select a high or low explosive depending on the type of work to be performed. For example, if a large boulder is blocking a dirt roadway, the experienced blaster might dig a hole under the boulder and place a black powder 399.9 m/s (1,312 ft/s) charge in the hole. When the black powder charge is functioned, it will heave the boulder, virtually intact, off the roadway. If the blaster wishes to reduce the boulder to rubble so that it may be removed, he might place a TNT

010.4 m/s (23,000 ft/s) charge on or under the boulder. When the TNT charge is functioned, the boulder will be shattered into many smaller pieces.

Another characteristic of explosives related to work performance is the fact that the forces created by a detonating explosive will be given off directionally at a 90° angle from the surface of the explosive. Consequently, if the explosive is cut or shaped to provide 90° surfaces along a predetermined plane, the explosive forces can be focused directionally, and will produce a greater effect, ounce for ounce, than the same explosive employed as a mass.
This improved effectiveness is caused by the focusing of the hot gases released by the detonating explosive. The extremely hot, swiftly moving bundle of concentrated power is called the “jet” and performs in much the same manner as the white-hot flame of a cutting torch.

A significant advance in the employment of explosives to accomplish specific work was achieved with the development of shaped or cavity charges that focus explosive forces. These specially shaped explosive charges are employed to cut or punch holes in steel, concrete, and other materials.

There are two basic types of shaped charges, the conical-shaped charge and the linear-shaped charge. Conical shaped charges are employed to cut or punch a hole through the target, while linear shaped charges are used to cut or slice a target.

Until recent years, the military were the primary users of shaped charges. Military shaped charges used in military projectiles, rockets, and mines were employed to destroy tanks and reinforced concrete bunkers. Today shaped charges are widely used in industry and by public safety personnel. One of the latest uses of the linear-shaped charge is as an explosive entry tool employed by fire fighters and public safety officers to cut through steel fire doors, roofs, and light structural walls. This shaped charge is manufactured under the name “Jet-Axe,” and consists of a linear-shaped charge contained in a polystyrene box. The box is placed against the target and the shaped charge is detonated, providing an entry hole to the building.

Two different sizes of prepackaged shaped charges are utilized by the armed forces in demolition and breaching operations against steel or reinforced concrete structures. The 6.82 kg (15-lb) M2A3 shaped charge and the 18.2 kg (40-lb) M3 shaped charge each contain a 50/50 pentolite/ composition B mixture. The armed forces also use various other shaped charges, both linear and conical, for special purposes, but these generally are small hand-packed charges employing composition C-3 or C-4 as the explosive filler.

EXPLOSIVE TRAINS

An explosive train is a series of explosions specifically arranged to produce a desired outcome, usually the most effective detonation or explosion of a particular explosive. The simplest explosive trains require only two steps, while the more complex trains of military munitions may have four or more separate steps terminating in detonation. Explosive trains are classified as either low (propellant) or high, depending upon the classification of the final material in the train.

Low-Explosive Trains
A round of small arms ammunition is a simple example of a two-step low-explosive train. The components in this train are a percussion primer and a propellant charge. The primer converts the mechanical energy of the weapon's firing pin into a flame. The flame ignites the propellant charge, and the gases produced by the resulting explosion drive the bullet through the bore of the weapon.

When low explosives, such as smokeless powder and black powder, are used in the construction of pipe bombs, a simple two-step explosive train is again required. A length of safety fuse, which is a slow-burning time fuse filled with black powder, is inserted into the pipe and the opposite end of the fuse is ignited with a match. The safety fuse transmits the flame, after a delay, to the low explosive inside the pipe. When it is ignited, the low explosive inside the pipe explodes, and the confined gases produced tear the pipe apart, resulting in both blast and fragmentation. The majority of low explosives require only a simple two-step train.

High-Explosive Trains
The nature of high-explosive trains is affected by the broad range of sensitivity found within the category of high-explosive compounds. Sensitivity refers to the amount of external force or effect needed to cause detonation. Some explosives are so sensitive that lightly brushing a small piece of explosive with a feather will cause it to detonate. On the other hand, other explosives may be placed on an anvil and struck with a sledge hammer and will not detonate.

For the sake of safety, the extremely sensitive explosives are always used in very small quantities, while the comparatively insensitive explosives are used in bulk quantities. This natural division, by sensitivity, produces two groups within the category of high explosives. The most sensitive explosives are referred to as primary high explosives, and the more insensitive compounds are termed secondary high explosives.

Primary High Explosives. Explosives known as primary high explosives are among the most powerful as well as the most sensitive of all chemical explosives. This combination of power plus sensitivity makes them very hazardous to handle. The primary high explosives, because of their sensitivity, may be initiated by applying shock, friction, flame, heat, or any combination of these conditions. Due to their high detonation velocities, the primary high explosives are able to create extremely powerful detonation waves capable of causing complete instantaneous detonation of other less sensitive explosives. For this reason they are used as the first step in high-explosive trains and are packaged for this purpose as blasting caps and military fuse detonators.

When used in both electric and nonelectric blasting caps, the primary high explosives are detonated by heat or flame. In military fuses, the primary high explosive is usually initiated by shock of impact or heat-producing friction. The more commonly used primary high explosives are lead styphnate, lead azide, mercury fulminate, and diazodinitrophenol, which have detonation velocities ranging from 5,029 m/s (16,500 ft/s) for mercury fulminate to 6,614 m/s (21,700 ft/s) for diazodinitrophenol.

Secondary High Explosives. Compared to the primary high explosives, the secondary high explosives are relatively insensitive to shock, friction, flame, or heat and are, therefore, less hazardous to handle and use. However, as a result of their relative insensitivity, the secondary high explosives must be initiated or detonated by a very strong explosive wave. Consequently, primary explosives are used to detonate secondary explosives.

Secondary explosives comprise the largest single class of explosives and have detonation velocities ranging from 2,743.2 m/s (9,000 ft/s) for some dynamites to 7,925 m/s (26,000 ft/s) for military composition C-4.

Boosters. Since there is a wide range of sensitivity found among the secondary high explosives, some of the more insensitive explosives cannot be detonated unless the detonation wave of the primary high explosive blasting cap is amplified or boosted. This amplification is accomplished through the use of a different and slightly more sensitive secondary explosive between the primary first step and the main explosive charge.
The progression of the detonation wave from a small amount of a sensitive primary high explosive, through a slightly larger amount of a less sensitive secondary high-explosive booster, to a large amount of very insensitive secondary high explosive main charge illustrates detonation through a basic three-step explosive train.

Typical High-Explosive Trains. The explosive train normally used in work with high explosives is a two- or three-step train. An example of a simple two-step train is an electric blasting cap containing a primary high explosive, and a stick of dynamite, as a secondary high explosive. The blasting cap is detonated by the heat generated by passing an electrical current through the fine wire imbedded in the primary high explosive inside the cap. The detonation wave from the blasting cap would cause the detonation of the dynamite. A simple three-step explosive train could be a length of safety fuse filled with black powder, a nonelectric blasting cap, and a stick of dynamite. The burning black powder in the safety fuse would produce a flame that would detonate the blasting cap, a primary high explosive, which would in turn detonate the dynamite, a secondary high explosive.

The number of steps in the explosive train is not always a matter of choice. As noted previously, some high explosives are so insensitive that the detonating wave from the blasting cap is not powerful enough to cause detonation. In such instances, a booster must be employed to amplify and strengthen the wave from the blasting cap.

Regardless of how many steps it contains, the firing train is nothing more than a series of explosions arranged to achieve a desired end result. If the explosive train is broken or interrupted, detonation of the main charge will not occur.

Some common explosives likely to be encountered by public safety personnel will be discussed next with information on the physical characteristics of the explosive material and its normal use and packaging. In addition, certain blasting accessories used to detonate the explosives will be discussed.

Low Explosives

Black Powder. The average composition of black powder is saltpeter (potassium nitrate), 75 parts by weight; sulfur, 10 parts by weight; and charcoal, 15 parts by weight. There has been, however, a wide variation in the black powder formulas that have been used over the years. The black powder mixture ranges in color from coal black to rusty brown and in form from a fine powder to granules as large as 1.27 cm (1/2 in) in diameter. The burning speed of black powder, and therefore to a certain extent its strength, is controlled by the size of the granulation. Large grains of powder burn more slowly than fine grains and are consequently less sudden in their action.

Black powder does not deteriorate with age, even if it has been submerged in water. Once black powder dries out, it is just as effective and dangerous an explosive as it was the day it was manufactured.

Sensitivity to friction, heat, impact, and sparks makes black powder one of the most dangerous explosives to handle. It is particularly sensitive to both electrically and nonelectrically generated sparks and should, therefore, be handled with wooden or plastic tools. As a further precaution, the body should be grounded before black powder is handled.

Because of its slow action and consequent heaving or pushing effect, black powder was for years the sole commercial blasting agent. Though it has been replaced by dynamite in most blasting applications, black powder is still used for certain special operations. For this purpose it is manufactured in varying granulations to enable the customer to match the powder to the specific application, and packaged in 11.36 kg (25-lb) metal kegs. For commercial blasting, black powder is also pressed into cylinders measuring 5.08 cm (2 in) by 3.175 cm (1 1/4 in). Some cylinders have a 0.9525 cm (3/8-in) hole through their center so that an electric squib may be inserted or so that the cylinders may be laced together on a length of fuse. In cylinder form, black powder is usually wrapped in paper to form a stick about 20.32 cm (8 in) in length and packed in 11.36 kg (25 lb) and 22.73 kg (50 lb) cases for sale.

As a blasting charge, black powder has about half the strength of TNT, and because the basic ingredients can be readily acquired in any community, it has become the favorite homemade explosive of bombers in the United States. Black and smokeless powder, whether homemade or commercial, will probably be the explosives most often encountered in pipe bombs. When confined inside a pipe and provided with a safety fuse, no blasting cap is needed to initiate the powder, because the flame from the end of the fuse is sufficient to cause the explosion of the bomb. It should be noted that any sparks resulting from an attempt to dismantle a pipe bomb may produce the same results. Therefore, a discovered pipe bomb should only be handled by specially trained personnel.

Perhaps the most common use of black powder in routine work with explosives is in the manufacture of safety fuse. Since its burning rate can easily be regulated in production, black powder is widely used as the core burning powder in the safety fuse used commercially, and by the military to provide a uniform delay time prior to an explosion.

Safety fuse is used for detonating explosives nonelectrically. Normally, its purpose is to transmit a flame at a continuous and uniform rate to a nonelectric blasting cap. There are two common burning rates for safety fuse. The most frequently encountered fuse burns at the rate of 40 s per 0.305 m, while a less common type is designed to burn at the rate of 30 s per 0.305 m.

Although safety fuse is designed for use with nonelectric blasting caps, it may, as previously noted, be used by bombers as a direct means of initiating a low explosive main charge. A delay element in itself, the safety fuse can be used to allow the bomber time to leave the scene of the incident. When employed in bombings, a portion of the spent fuse will usually survive the explosion and may be located not far from the point of detonation.

- **Commercial Safety Fuse**. There are numerous brands of commercial safety fuse, but their only essential difference is in the type of exterior water proofing materials and color markings. Commercial safety fuse is approximately 0.508 cm (0.2 in) in diameter, about the size of a lead pencil, and comes in 15.24 m (50 ft), paper wrapped, rolls or coils. It is colored orange for general use, black for use in salt mines, and white for use in coal mines.

- **Military Safety Fuse**. The U.S. military uses two types of safety fuse, one called "safety fuse" and the other called "M 700 time fuse." They are interchangeable in use and similar in construction.

- **Improvised Safety Fuse**. Fusing can be made from a common fireworks fuse, or by saturating ordinary cotton cord with certain liquid chemical compounds that provide uniform burning when dry. Even the use of rag wicks in fire bombs such as the "Molotov cocktail" can be considered a form of improvised fusing. Since most improvised fuses burn at erratic rates, they can hardly be considered "safety" fuses.

Smokeless Powder. Smokeless powder is the world standard propelling powder for small arms, cannons, and, in a slightly different form, rockets. All low explosives currently used as propellants have a nitrocellulose base and are commonly referred to as smokeless powders. Various organic and inorganic substances are added to the nitrocellulose base during manufacture to give improved qualities for special purposes, and these variations are distinguished by such terms as double-base, flashless, and smokeless, as well as by various commercial trade names or symbols.

Smokeless powders are produced by dissolving guncotton (nitrocellulose) in a mixture of ether and alcohol to form a mass called a colloid. The colloid has the consistency of melted glue, and is squeezed into macaroni-shaped tubes that are subsequently cut into short lengths. The ether and alcohol used to dissolve the guncotton are evaporated, leaving a hard substance. The small cylindrical powder grains resulting from this process are used as rifle ammunition powders.

Pistol powders, unlike rifle powders, do not generally have cylindrical grains. Instead, they are manufactured in the form of very fine, thin wafers, flakes, or balls. These shapes insure the shorter burning time necessary for full combustion in weapons with short barrels. Shotgun powders are similar to pistol powders in that they burn more rapidly than rifle powders. In fact, most shotgun powders are straight nitrocellulose in composition.

Like black powder, smokeless powders vary widely in both form and color. The majority of rifle and pistol powders are black in color and are formed into rods, cylindrical strips, round flakes, or irregular grains. Shotgun powders may be translucent round or square flakes, orange to green in color, or may be black irregularly shaped granules. Smokeless powders of all types are sold in tin flasks, glass jars, plastic containers, and kegs of varying weights up to 11.36 kg (25 lb).

Unconfined smokeless powder burns with little or no ash or smoke and, when confined, its rate of burning increases with temperature and pressure. For this reason, it is frequently used in the construction of pipe bombs. It should be noted that smokeless powder manufactured for use in small arms ammunition is usually glazed with graphite to facilitate machine loading and prevent the accumulation of static electricity. Many of these powders are as sensitive to friction as black powder, and the precautions used in handling black powder should be observed for smokeless powders.

Primary High Explosives

Primary high explosives are sensitive, powerful explosives used in blasting caps, military fuse detonators, and detonating cord to detonate main charges or secondary high explosives.
Blasting Caps. Blasting caps are used for initiating high explosives and contain small amounts of a sensitive primary high explosive. Although they are manufactured to absorb a reasonable amount of abuse under normal conditions, they must be protected from shock, extreme heat, impact, and rough treatment to prevent accidental detonation. Blasting caps are functioned either electrically or nonelectrically.

Electric Blasting Caps. Electric blasting caps are used when a source of electricity, such as a blasting machine or battery, is available. The electric cap is constructed from a small metal tube or shell which is closed at one end. The cap contains a base load of a sensitive high explosive, a pressed intermediate charge of extremely sensitive explosive, and a loose ignition charge. The electrical firing element consists of two plastic insulated leg wires (also called lead wires), an insulated plug which holds the two wires in place, and a small diameter corrosion-resistant bridge wire attached across the terminals of the leg wires below the plug. This assembly is double crimped into the cap shell.

Upon application of electric current, the bridge wire heats to incandescence and ignites the loose ignition mixture. The resulting heat or flame sets off the extremely sensitive intermediate charge which, in turn, detonates the base charge.

Commercial electric blasting caps come in a variety of sizes, with the Number 6 and Number 8 blasting caps being the most common. Number 6 blasting caps are approximately 2.8575 cm (1 1/8 in) long, with an outside diameter of 0.635 cm (1/4 in). Number 8 blasting caps have the same diameter and are about 3.175 cm (1 1/4 in) long. Electric blasting caps with leg or lead wires 7.315 m (24 ft) long or less are normally packed 50 to a carton and 500 caps to the case. Leg or lead wires, which come in lengths ranging from 1.22 m to 91.44 m (4 ft to 300 ft), are made of 22 gauge copper wires for lengths up to 7.315 m (24 ft) and 20 gauge copper for longer lengths. Most commercial blasting caps employ lead wires of two different colors to facilitate making electrical connections.

Most electric blasting caps have a short circuiting shunt on the exposed ends of the leg wires to act as a guard against static electricity and to prevent accidental firing.

Special types of electric blasting caps are manufactured for seismographic work, open hearth steel furnaces, and other tasks requiring very short delays. The delays built into these special blasting caps range from 0.5 ms to 1.5 ms and are indicated by tags attached to each blasting cap.

Nonelectric Blasting Caps. Nonelectric blasting caps are small metal tubes or shells, closed at one end, which contain a charge of one or more of the very sensitive primary high explosives. They are designed to detonate from the flame provided by a safety fuse or other flame-producing device. Nonelectric blasting caps have a charge of sensitive high explosive in the base of the cap, with a priming load of extremely sensitive explosive in front of the base charge, and an ignition load superimposed upon the priming explosive. In functioning, the burning safety fuse ignites the ignition charge, which sets off the priming explosive, which, in turn, detonates the base charge.

The most common commercial nonelectric blasting caps are Number 6 and Number 8 with aluminum or copper shells. Number 6 caps are 3.4925 cm (1 3/8 in) long and Number 8 are 3.81 cm (1 1/2 in) long with outside diameters of approximately 0.635 cm (1/4 in). Some nonelectric caps may be larger. For example, the standard issue U.S. Army Corps of Engineers Special Number 8 blasting cap is 5.969 cm (2.35 in) long and 0.612 cm (0.241 in) in diameter. The larger size must accommodate the larger base charge required to detonate the less sensitive military explosives. Nonelectric blasting caps are packaged in a variety of containers, including metal cans, cardboard boxes, and wooden boxes.

The explosives normally employed in both electric and nonelectric blasting caps are the following:

- **Lead Azide.** Lead azide is an excellent initiating agent for high explosives and is used extensively as the intermediate charge in the manufacture of blasting caps. It is inferior to mercury fulminate in detonating the less sensitive main charge explosives like TNT, but is superior as an initiator for the more sensitive booster explosives such as tetryl, RDX, and PETN. Lead azide is extremely sensitive to heat, shock, friction, and static electricity. The form of lead azide normally used in blasting caps and fuse detonators is dextrinated lead azide. It is white to buff in color and is manufactured in the form of rounded aggregates having no visible crystal faces.

- **Lead Styphnate.** Lead styphnate is a relatively poor initiating explosive, and is used primarily as an ingredient of priming compositions and as a cover charge for lead azide to make the lead azide more sensitive to detonation. It is used as the ignition charge in blasting caps. Lead styphnate is light orange to reddish-brown in color and its crystals are rhombic in shape. This explosive is extremely sensitive to heat, shock, friction, and static electricity.

- **RDX or PETN.** These secondary explosives are typically used as the output charge in blasting caps. They are very powerful and have a high brisance value.

Detonating Cord. Detonating cord is a round flexible cord containing a center core of primary high explosive. The explosive core of the detonating cord is protected by a sheath of various textiles, waterproofing materials, or plastics.

The function of the protective sheath is to prevent or minimize damage to the explosive core from abrasion or moisture. Various colorings and textile patterns are used to identify different strengths and types of detonating cord.

While detonating cord has a general resemblance to safety fuse in that it has the same diameter and is supplied in rolls or coils, detonating cord is always distinguishable by its white powder core of PETN (pentaerythritol tetranitrate), an extremely powerful explosive. Pure PETN is white in color, but the addition of desensitizers may change its color slightly from pure white to light gray. PETN has no identifiable odor.

Detonating cord is frequently known by a brand name such as Primacord, Primex, Detacord, Detonating Fuse, or Cordeau Detonant. Most of the common detonating cords are of the high energy military type, which contains about 60 gr of PETN per foot. Detonating cords up to 400 gr per foot are manufactured for special purposes. There are other lower energy detonating cords designed for specific applications, especially for operations in developed areas where a diminished noise level is desired. For example, one low-energy cord, Detacord, has been developed with a core of only 18 gr of PETN per foot. Other low-energy cords include Mild Detonating Fuse and E-Cord, both with reduced core loading per foot.

Detonating cord is used to detonate charges of high explosives in the same manner as blasting caps and for the same purpose. The detonating cord with its primary high-explosive core may be tied around, threaded through, or knotted inside explosives to cause them to detonate.

Detonating cord is most commonly used when a simultaneous detonation of a number of explosive charges is planned and when it is not practical to use electrical circuits for this purpose. For example, to simultaneously detonate 10 dynamite charges placed 60.96 m (200 ft) apart in a straight line would require a minimum of about 548.64 m (1,800 ft) of electric firing wire and a considerable amount of time to prepare and test the electrical circuit. In contrast, a single line of detonating cord can be laid out from the firing point in a path that will pass near all of the dynamite charges. This long line is known as a trunk line. Shorter lengths of detonating cord, called down lines or branch lines, are attached to the charges and tied into the trunk lines.

When a blasting cap is attached to one end of the trunk line and detonated, the detonating wave produced is transmitted through the trunk line and all the down lines to detonate the dynamite charges simultaneously. The detonating wave travels at approximately 6,400 m (21,000 ft) or nearly 6.44 km (4 miles) per second.

Secondary High-Explosive Boosters

Secondary high-explosive boosters are explosives that provide the detonation link in the explosive train between the very sensitive primary high explosives (blasting caps) and the comparatively insensitive main charge high explosives, which are also called primer explosives or simply primers. The explosives packaged for use as boosters are relatively sensitive and must be handled carefully. Most, for example, will detonate on sharp impact such as that resulting from a small arms bullet. Due to this sensitivity, boosters are normally used in small amounts ranging from several grams up to a 0.5 kg (1 lb) in weight.

Boosters are usually cylindrical in shape with the explosive encased in a light metal, cardboard, or plastic container. Generally there is an opening in the end of the booster container to permit the insertion of a blasting cap or to allow the threading of detonating cord. Boosters packaged in metal containers are usually employed in wet blasting operations, such as seismic prospecting or underwater channel cuttings. Cardboard and plastic encased primers or boosters of varying sizes are generally used in dry blasting operations, where they are often strung or laced on a length of detonating cord and lowered into a borehole. After the placing of the booster, insensitive main charge explosives in prill (loose) or slurry (liquid-gel mix) form are poured into the borehole. When the charge is fired, the boosters ensure complete detonation of the main charge explosives.

Several secondary high explosives are commonly used as primers or boosters. These explosives are frequently mixed for booster use and, in some instances, are cast together in a homogeneous mixture or are formed with one type of explosive cast around or over the other. Common explosives used in boosters include:

- **Pentolite.** Pentolite is a very commonly employed booster explosive. It consists of a homogeneous mixture of 50 percent PETN and 50 percent TNT. Cast pentolite varies in color from gray to yellow and has a detonation velocity of 7,315 m/s (24,500 ft/s).

- **RDX.** Alone and mixed with other explosives, RDX is used in several commercial primers and boosters. The Titan Booster 25 is designed primarily for underwater work. It consists mainly of RDX in a 11.43 cm by 1.5875 cm (4 1/2 in by 5/8 in) aluminum tube with a cap well located at one end, giving the appearance of an oversized blasting cap.

- **PETN.** Described earlier as a filler for detonating cord, PETN is also used as a booster. It is most commonly used to boost ammonium nitrate and other cap insensitive explosives.

- **Tetryl.** Tetryl is the most common military booster. It is yellow in color, but may appear gray if graphite has been added. Tetryl is a very powerful explosive with a satisfactory initiating power which is also used in the manufacture of primary and secondary charges for blasting caps. When used as a booster, tetryl is usually found in pellet form.

Secondary High-Explosive Main Charges

Dynamite. Dynamite is the explosive most widely used for blasting operations throughout the world. In the past, dynamite has been relatively easy to obtain by theft or through legal purchase in the United States. While dynamites are generally used in earth-moving operations, they differ widely in their explosive content and, therefore, in their strength and sensitivity. Commercial dynamites are made of either liquid nitroglycerin, ammonium nitrate, or nitroglycol (EGDN), along with oxidizers and a binding material.

The percentage strength of commercial straight dynamite is the gauge by which the strength of all other commercial dynamite variations are measured. This measurement is based upon the percentage of nitroglycerin by weight present in its formula. This percentage value can be misleading, however, in determining actual blasting power. For example, a 60 percent dynamite is not necessarily three times as powerful as one marked 20 percent, because the nitroglycerin is not the only energy-producing ingredient present in the total composition.

Unless it is packaged loose in boxes or bags for specialized applications, dynamite will usually be found in cylindrical form, or sticks, wrapped in colored wax paper. These sticks or cartridges are obtainable in a variety of lengths and diameters. The most common sizes range from 2.8575 cm (1 1/8 in) to 3.81 cm (1 1/2 in) in diameter and are about 20.32 cm (8 in) long. In less common larger sizes, dynamite cartridges may be 10.16 cm to 15.24 cm (4 in x 6 in) in diameter and up to 96.52 cm (38 in) in length. Because of the wide variety of formulas, ingredients, and packaging, dynamite is not always easy to identify. Consequently, any packaging materials available should be retained as a means of determining the actual composition and strength of recovered dynamite.

In addition to its illegal use in bomb construction, dynamite also provides a source of liquid nitroglycerin for use in safe and vault burglary. Through a dangerous operation called milking, nitroglycerin is obtained by boiling, heating, or straining the dynamite through a fine fabric such as silk. The boiling process is also referred to as sweating, with the separated nitroglycerin being skimmed from the surface of the pot. In any event, the resulting nitroglycerin is almost always impure and highly unstable.

Although dynamite is available in an almost unlimited number of sizes, shapes, strengths, and packages, there are essentially only five basic types of dynamite in use today.

Straight Dynamites. The explosive base of straight dynamite is liquid nitroglycerin absorbed in a mixture of various carbonaceous materials, such as wood pulp or ground meal. Sodium nitrate is added primarily to supply oxygen for complete combustion of the carbonaceous materials, thereby increasing the strength of the explosive.

Straight dynamite, because of the nitroglycerin content, has a heavy, pungent, sweet odor, which is its most outstanding identification feature. Inhalation of straight dynamite fumes, even for short periods of time, will usually cause a persistent and severe headache.

When removed from its wrapper, straight dynamite is light tan to reddish-brown in color. While they vary in texture, the straight dynamites can be described as loose, slightly moist, oily mixtures, much like a mixture of sawdust, clay, and oil. Straight dynamites have been manufactured in percentage ratings of 10 percent to 60 percent, with the more common ratings being 30 percent, 40 percent, 50 percent, and 60 percent.

Straight dynamites are rarely used in general blasting work because of their high sensitivity to shock and friction and their high flammability. When detonated, they produce toxic fumes, which makes them unsuitable for use underground or in confined spaces. Because of their high nitroglycerin content, straight dynamites are the most hazardous of the dynamites to handle and store. Boxes or sticks of straight dynamite in storage must be periodically inverted to prevent the nitroglycerin content from settling to the bottom and leaking out of the stick. Public safety personnel should be extremely cautious of any dynamite that appears to be deteriorating or leaking any oily substance. In such cases, the material should be moved only by trained bomb technicians.

A form of straight dynamite that is widely used in commercial blasting operations is known as ditching dynamite. Ditching dynamite is manufactured in a 50 percent grade in sticks 3.175 cm by 20.32 cm (1 1/4 in by 8 in) for use in ditch blasting. The principal characteristic of ditching dynamite is its high detonation velocity of over 5,181.6 m/s (17,000 ft/s), which imparts a powerful shock wave and produces a large earth-shattering effect.

Ammonia Dynamites. In the manufacture of ammonia dynamites, a portion of the nitroglycerin content is replaced by ammonium nitrate and nitroglycol (EGDN). This produces a dynamite which is lower in cost and less sensitive to shock and friction than straight dynamite. Since it has a less shattering effect, ammonia dynamite is more suitable for pushing or heaving kinds of work such as quarry operations, stump or boulder blasting, and hard pan gravel or frozen earth blasting. Due to these characteristics, ammonia dynamites are probably the most widely used explosives of the dynamite family.

Ammonia dynamites are generally manufactured in percentage strengths, from 20 percent to 60 percent, with detonation velocities in the range of 2,133.6 m to 2,743.2 cm (7,000 ft/s to 9,000 ft/s). However, special purpose formulas producing velocities from 1,981 m/s to 3,718 m/s (6,500 ft/s to 12,200 ft/s) can be obtained.

When the wrapper is removed, ammonia dynamite will appear light tan to light brown in color and will have a pulpy, granular, slightly moist, oily texture. It has the same odor as straight dynamite because of its nitroglycerin content and may produce severe headaches after short periods of contact.

Gelatin Dynamites. Gelatin dynamites have a base of water resistant "gel" made by dissolving or colloiding nitrocellulose with nitroglycerin. The gel varies from a thick, viscous liquid to a tough, rubbery substance. Gelatin dynamite avoids two of the disadvantages of straight ammonia dynamite in that it is neither hydroscopic or desensitized by water. Since it is insoluble in water and tends to waterproof and bind other ingredients with which it is mixed, gelatin dynamite is well suited for all types of wet blasting work. Because of its density, it is also used extensively for blasting very hard, tough rock or ore.

Gelatin dynamites and semi-gelatin dynamites are manufactured in percentage strengths from 20 percent to 90 percent. It is an inherent property of gelatin dynamite to detonate at two velocities. Unconfined, it will usually detonate at about 2,133.6 m/s (7,000 ft/s), but when confined gelatin dynamites will detonate in the range of 3,962.4 m/s to 6,705.6 m/s (13,000 ft/s to 22,000 ft/s), depending upon the strength of the dynamite employed.

Ammonia-gelatin Dynamites. These dynamites retain most of the characteristics and qualities of gelatin dynamite, but derive a portion of their strength from the use of less costly ammonium nitrate. Ammonia-gelatin dynamites are manufactured in percentage strengths of 25 percent to 90 percent with detonating velocities ranging from about 3,962.4 m/s (13,000 ft/s) to 5,181.6 m/s (17,000 ft/s).

Military Dynamites. Military dynamite is not a true dynamite. It is manufactured with 75 percent RDX, 15 percent TNT, 5 percent SAE 10 motor oil, and 5 percent cornstarch. It is packaged in standard dynamite cartridges of colored wax paper and is marked either M1, M2, or M3 on the cartridge. This marking identifies a cartridge size difference only, since all military dynamite detonates at about 6,096 m/s (20,000 ft/s).

Military dynamite is used as a substitute for commercial dynamites in military construction, quarry work, and demolitions. It is equivalent in strength to 60 percent straight dynamite.

Since it contains no nitroglycerin, military dynamite is safer to store and transport than true dynamite, and is relatively insensitive to heat, shock, friction, or bullet impact. These qualities permit safer combat operations while providing the pushing or heaving action not available from standard combat demolition explosives. When removed from its wrapper, military dynamite is yellow-white to tan in color and is a granular substance which crumbles easily and is slightly oily. It does not have a noticeable characteristic odor, nor does it cause the headaches typical of the true dynamites.

Ammonium Nitrate. Ammonium nitrate is one of the least sensitive and most readily available main charge high explosives. It ranges in color from white to buff-brown or gray, depending upon its purity, and has a salty taste. Ammonium nitrate is usually found in the form of small compressed pellets called prills. While it is extensively used as a blasting agent and by the military as a cratering charge, it is also an ingredient in the manufacture of certain dynamites and is widely employed as a fertilizer.

Even a high-explosive grade of ammonium nitrate generally requires the use of a booster for detonation. For military cratering charges, TNT is used as the booster, while in commercial applications RDX-filled boosters or primers are usually employed. The normal detonation velocity of ammonium nitrate is approximately 3,352.8 m/s (11,000 ft/s). Due to its hygroscopicity and the fact that it loses power and sensitivity in direct proportion to its moisture content, explosive charges composed of ammonium nitrate are usually packaged in some form of waterproof container.

Its use as a commercial fertilizer makes ammonium nitrate readily accessible to anyone. While the grade of ammonium nitrate used as fertilizer is naturally inferior as an explosive charge, it can be sensitized by the addition of fuel oil. The mixture is referred to as “prills and oil” or ANFO (ammonium nitrate and fuel oil), and its use is fairly widespread because of its low cost and availability.

Ammonium nitrate should be handled with some degree of caution, because it is a strong oxidizing agent and has the ability to increase the combustibility of other flammable materials with which it comes in contact. If it is recovered as the result of a bombing incident, brass or bronze nonsparking tools should not be employed because they react with the ammonium nitrate to form tetramino nitrate, which is as sensitive an explosive as lead azide.

Blasting Agents

A blasting agent is an insensitive chemical composition or mixture, consisting largely of ammonium nitrate, which will detonate when initiated by high-explosive primers or boosters. Since they contain no nitroglycerin, blasting agents are relatively insensitive to shock, friction, and impact and are, therefore, safer to handle and transport.

One group of blasting agents are called nitro-carbo-nitrates (NCN). NCN is manufactured mainly of ammonium nitrate and oil, with special ingredients added to reduce static electricity and prevent hardening of the agent during storage. It is packaged in sealed waterproof cans, asphalt laminated paper, and flexible plastic bags which provide water resistance as long as the containers are not opened or damaged. Container sizes range from 10.16 cm to 27.94 cm (4 in to 11 in) in diameter, 40.64 cm to 60.96 cm (16 in to 24 in) in length, and weigh from 6.136 kg to 38.636 kg (13.5 lb to 85 lb). NCN is similar to 50 percent or 60 percent blasting gelatin in strength, but is much less sensitive. NCN cannot normally be detonated with a blasting cap or detonating cord alone, but requires a high-explosive booster.

Free-running explosives consisting of NCN, either with or without the addition of high explosives, make up another group of blasting agents. Because of their granular or small pellet form, the free-running agents can be poured around rigid explosive charges to fill all of the available space in the borehole. They are also useful for pouring into rough, irregular, or partially blocked holes, and some free running blasting agents can be submerged underwater for a period of time without loss of effectiveness. Sometimes an orange dye is added to the agent to facilitate visibility.

A final common group of blasting agents are called blasting slurries. These consist of NCN mixtures, with or without the addition of TNT, in a gel-like consistency. Some of the blasting slurries have powdered metals, such as aluminum, added to increase their performance. The blasting slurries, because of their consistency, can be poured into irregular or wet boreholes to fill all available space with explosive. Like all of the previously discussed blasting agents, the blasting slurries require a primer or booster for detonation.

Two-Part Explosives

Kine-Pak and Kine-Stick explosives are two-part explosives, consisting of ammonium nitrate and nitromethane, which are inert until mixed. When mixed and detonated with a Number 6 cap, Kine-Pak generates 50 percent more shock energy than 75 percent dynamite. Following mixture and prior to detonation, it is some 20 times less shock or impact sensitive than dynamite. The Kine-Pak and Kine-Stick explosives were developed as a direct replacement for dynamites and commercial PETN-RDX boosters, and are manufactured by the Atlas Powder Company.

Liquid Explosive - Astrolite. Astrolite is a liquid explosive developed for commercial and military applications. Although it is almost twice as powerful as TNT, Astrolite cannot be detonated until its two separate components are mixed.

Astrolite comes in two plastic bottles labeled Astropak. The smaller bottle contains a dry solid component (proprietary, but assumed to be ammonium nitrate), and the larger bottle contains a liquid-filled can (slightly aqueous hydrazine) in the bottom. To form the explosive, the contents of the small bottle are poured into the larger bottle and the top replaced. By pressing down on the bottle cap, cutters automatically puncture the liquid-filled can. By inverting and shaking the bottle, the two components are mixed and are ready for detonation with a standard blasting cap. The liquid can be detonated in its container or poured into crevices in the ground, cracks in rocks, or into other containers. Astrolite is clear in color and smells strongly of ammonia. Additional information on Astrolite may be obtained from the Explosives Corporation of America, Excca Building, Issaquah, WA 98027.

Military Explosives

Explosives made for military use differ from commercial explosives in several respects. Military explosives, designed to shatter and destroy, must have high rates of detonation and, because of combat conditions, must be relatively insensitive to impact, heat, shock, and friction. They must also possess high power per unit of weight, must be usable underwater, and must be of a convenient size, shape, and weight for troop use.

Trinitrotoluene (TNT). TNT is probably the most widely used military explosive in the world. Alone or in combination with other explosives, it is frequently used as a main charge in artillery projectiles, mortar rounds, and aerial bombs. As one of the moderately insensitive military explosives, TNT cannot be detonated by heat, shock, or friction and is, in fact, safe even when impacted by a bullet. It will usually burn rather than detonate if consumed by fire.

The TNT most often encountered by public safety personnel will probably be in the form of the 0.638 cm (1/4-lb), 1.27 cm (1/2-lb), and 0.4545 kg (1-lb) blocks. These blocks are normally packed in 22.727 kg (50-lb) wooden boxes for storage or transportation. When TNT is removed from the cardboard container, it is light yellow to light brown in color and gradually turns dark brown after several days' exposure to sunlight. Detonated TNT gives off a dirty gray smoke.

Tetrytol. Tetrytol is used as an alternative to TNT by the armed services and is composed of about 75 percent tetryl and 25 percent TNT. It is light tan to buff in color and has a detonation velocity of about 7,315.2 m/s (24,000 ft/s).

Tetrytol is manufactured for the military both as part of the M1 chain demolition package and as the M2 demolition block. When the present stocks are exhausted, no more tetrytol will be procured by the U.S. military services.

Composition C-3. Composition C-3 is a plastic explosive containing approximately 80 percent RDX and 20 percent explosive plasticizer. It is a yellow putty-like substance which has a distinct, heavy, sweet odor. When molded by hand in cold climates, C-3 is brittle and difficult to shape. In hot climates it is easy to mold, but tends to stick to the hands. C-3 will most likely be encountered by public safety personnel in the form of demolition blocks.

Composition C-4. Composition C-4 is an improved version of the C-3 explosive. It contains 90 percent RDX and has a greater shattering effect than the earlier C-3. C-4 is white to light tan in color, has no odor, and detonates at about 7,315.2 m/s (24,000 ft/s).

Sheet PETN (Flex-X). Sheet PETN, called Flex-X by the military and Detasheet commercially, is a demolition charge consisting of 63 percent PETN with nitrocellulose and plasticizer added. It comes in the form of sheets, with each sheet having a pressure-sensitive adhesive backing, making it possible to apply the sheet to almost any dry surface.

Commercially, sheet PETN is used for explosive forming, cutting, and metal hardening. The military sheet is supplied only in an olive green color, but commercial sheets may range from pink to brownish-red.

Improvised Explosives

When manufactured explosives are not available, it is relatively easy to obtain all of the ingredients necessary to improvise explosive materials. The list of existing materials and simple chemical compounds which can be employed to construct homemade bombs is virtually unlimited. The ingredients required can be obtained at local hardware or drug stores and are so commonplace that their purchase rarely arouses suspicion.

Starch, flour, sugar, or cellulose materials can be treated to become effective explosives. Powder from shotgun shells or small arms ammunition, match heads, firecracker powder, and ammonium nitrate fertilizers can all be accumulated in sufficient volume to create a devastating main charge explosive. To explode or detonate the improvised main charge, some means of initiation is required. The most common methods of ignition of improvised explosives are summarized below:

- **Blasting Caps.** Blasting caps, when available, provide the most successful means of causing the complete detonation of improvised explosives.

- **Percussion Primers.** Shotgun, rifle, or pistol ammunition primers have served as initiators in mechanically functioning bomb assemblies, particularly with explosives that are sensitive to heat.

- **Flashbulbs.** Although not explosive by nature, carefully prepared flash bulbs or light bulbs can be used as initiation devices when placed in contact with explosive materials that are sensitive to heat and flame. They can be functioned electrically to provide the necessary heat required to ignite black powder, smokeless powder, and other heat-sensitive explosive or incendiary mixtures.

Possible improvised main charge explosives are listed below:

- **Match Heads.** A main charge explosive consisting of ordinary match heads confined inside a steel pipe will produce an excellent explosion. Bombs filled with match heads are extremely sensitive to heat, shock, and friction, and must be handled with care.

- **Smokeless Powder.** Smokeless powder, obtained from assembled cartridges or purchased for hand reloading, is widely employed as a main charge, particularly in pipe bombs.

- **Ammonium Nitrate Fertilizer.** Fertilizer grade ammonium nitrate mixed with fuel oil or potassium nitrate and charcoal makes an excellent main charge explosive. A booster would be required for detonation.

- **Potassium/Sodium Chlorate.** Potassium chlorate or sodium chlorate and sugar mixtures are widely used as incendiary and explosive materials. Though essentially incendiary compounds, these mixtures will explode with a violence comparable to 40 percent dynamite when initiated in confinement.

Nitroglycerin

Although nitroglycerin is not often employed as a main charge either in its manufactured or improvised state, it is the main explosive component of straight dynamite and is found in lesser concentrations in a number of other explosives. Other applications include medical use, oil and gas well drilling, and the blowing open of safes and vaults by criminals. Liquid nitroglycerin may also be encountered as leakage from badly deteriorated dynamite.

Nitroglycerin is an oily liquid which is not mixable with and is about 1.6 times heavier than water. It may be anything from clear and colorless to amber in color and has been found looking almost milky. Brown fumes in a bottle of nitroglycerin are due to nitric acid and indicate decomposition and, thus, increased hazard. It is almost odorless, although there may be an acrid odor due to the presence of acid.

In a pure state, nitroglycerin is very sensitive to heat, shock, and friction. Sensitivity increases markedly by the application of heat. When frozen, nitroglycerin is less sensitive than when it is in a liquid state, but in a semifrozen state it becomes extremely sensitive due to the internal crystal stresses brought about by freezing or thawing action. Even under ideal conditions, nitroglycerin is an extremely dangerous explosive to handle and can explode from such causes as a slight jarring, overheating, or chemical reaction with container materials and impurities. In certain cases, it has been known to detonate for no apparent reason at all.