INTRODUCTION TO EXPLOSIVES

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A PUBLICATION OF **The National Bomb Data Center**

Research Division ☐ **International Association of Chiefs of Police**

A program funded by the Law Enforcement Assistance Administration of the United States Department of Justice. Dissemination of this document does not constitute U. S. Department of Justice endorsement or approval of content.

INTRODUCTION TO EXPLOSIVES

The purpose of this publication is to provide public safety personnel with 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 fire officials who find themselves involved in the prevention and control of the illegal use of explosives in the United States.

SECTION ONE

EXPLOSIONS

TYPES OF EXPLOSIONS

An explosion may 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 criteria of an explosion and is present in each of the three basic types of explosions known to man.

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 or 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 are generated. When a block of explosive detonates, the produced gases will expand 10,000 to 15,000 times greater than the original volume of the explosive. The expansion of these generated gases is quite rapid, reaching velocities of approximately 5 miles per second. Temperatures generated by the conversion of a solid into a gas state may reach 3,000° to 4,000° C. The entire conversion process takes only a fraction of a second and is accompanied by shock and loud noise. All explosives manufactured by man are chemical explosives with the single exception of atomic explosives.

Atomic Explosion

An atomic explosion may be induced either by fission, the splitting of the nucleus of atoms, or fusion , the joining together under great force of the nuclei of atoms. Nuclear fission or fusion occurs only in extremely dense and heavy elements which are atomically unstable or radioactive. When fission of fusion occurs, 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 20,000 tons (20 KT), or 40 million pounds, of TNT in explosive power, yet the amount of fissionable material required to produce this energy weighed approximately 2.2 pounds.

NATURE OF CHEMICAL EXPLOSIONS

The explosives normally encountered by public safety 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.

Ordinary Combustion (Slow Combustion)

For combustion to occur, a combustible material (something that can be burned) and a supporter of combustion (something that will stimulate burning) must be brought together and the temperature raised to the point of ignition. The most effective supporter of combustion is oxygen. Air, which contains 23 parts of oxygen, serves as the most common source of support for combustion. In ordinary combustion, which is a common occurrence, the elements of the combustible material unite with elements of the supporter to form a new and different product.

To build a fire of large logs, it is first necessary to lay a foundation of combustible material, such as paper or wood shavings, which has a low ignition temperature. Next a layer of small kindling is added and, finally, the logs are placed in position. Beginning with the lighting of the match, the process of combustion is progressive and each layer of material is ignited as its ignition point is reached. As long as fuel and oxygen are supplied, combustion will continue, heat will be created, and gases will be formed and then released. Flames, which are particles heated to incandescence, and smoke, which are unoxidized particles suspended in air, will be visible. In normal combustion, this progressive sequence can be followed visually and is essentially the same process which occurs at a greatly increased rate in a chemical explosion.

Explosion (Rapid Combustion)

An example of explosion 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 explosion occurs. An explosion is merely a rapid form of combustion, and ordinary combustion is simply a slow form of explosion. The speed of the burning action constitutes the difference between combustion, explosion, and detonation.

Detonation (Instantaneous Combustion)

Detonation can be defined as "instantaneous combustion." However, even in detonation, the most rapid 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 9,000 feet per second to over 27,500 feet per second. As an illustration of detonation velocity, if a 5 mile (26,400 feet) length of garden hose were filled with a high explosive called RDX (detonation velocity 27,500 f.p.s.) and initiated at one end, the detonation would reach the other end of the 5 mile long hose in less than one second.

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 these factors:

- Initiator (blasting cap) of inadequate power
- Deterioration of the explosive
- Poor contact between the initiator and the explosive
- Lack of continuity in the explosive (air spaces)

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 as illustrated in figure 1.

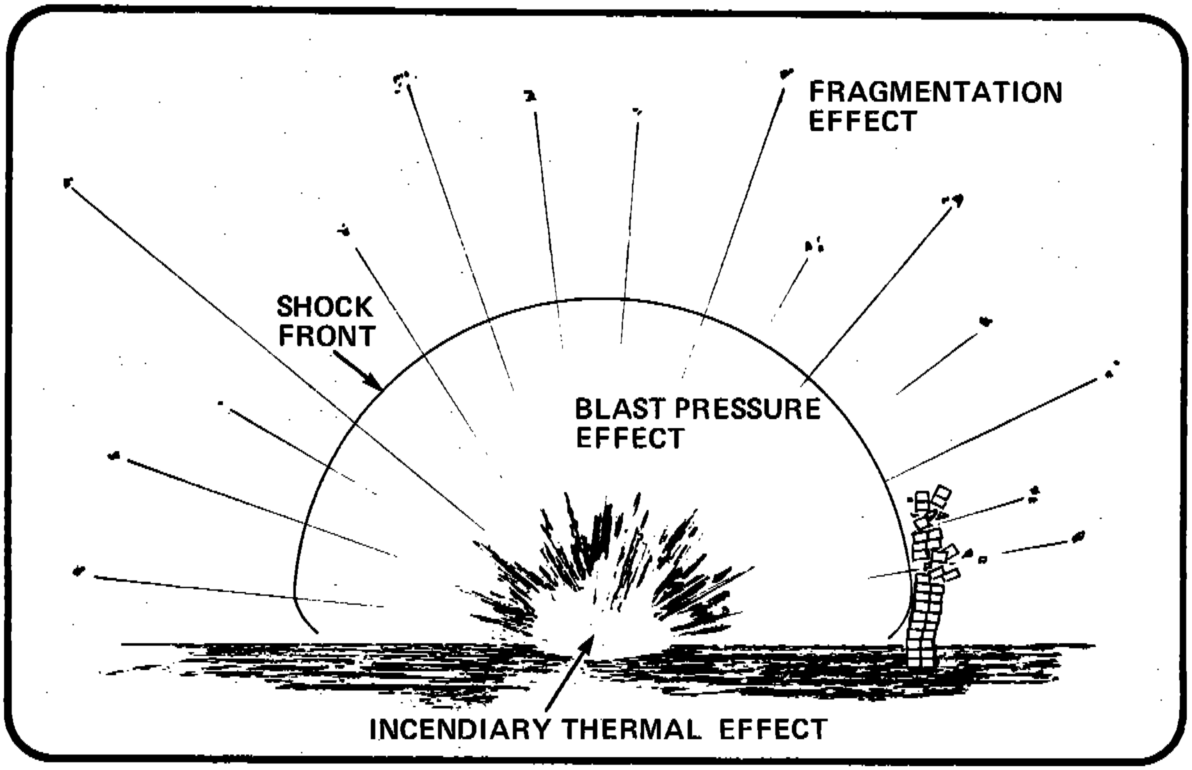

Figure 1
EFFECTS OF AN EXPLOSION

Blast Pressure Effect

When an explosive charge is detonated, very hot, expanding gases are formed in a period of approximately 1/10,000th of a second. These gases exert pressures of about 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 7,000 miles per hour, 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. Like an ocean wave rushing up on the beach, 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 Positive Pressure Phase. When the blast pressure wave is formed at the instant of detonation, the pressures actually compress the surrounding atmosphere. This compressed layer of air becomes visible in some cases as a white, rapidly expanding circle. Known as the *shock front*, this layer of compressed air is the leading edge of the positive pressure wave. The shock front is only a fraction of an inch thick and is that part of the atmosphere which is being compressed before it is set in motion to become part of the positive pressure wave.

As the shock front, followed by the positive pressure wave, moves outward, it applies a sudden shattering, hammering blow to any object in its path. Thus, if it should strike an object such as a brick garden wall, the shock front will deliver a massive blow to the wall followed instantly by the strong winds of the positive pressure wave itself. The shock front shatters the wall, and the positive pressure wave gives it a cyclone-like sudden and violent push which may cause all or part of the wall to topple in a direction away from the point of detonation. The positive pressure phase lasts only a fraction of a second. After striking the wall, the positive pressure wave continues to move outward until its power is lost in the distance traveled. Figures 2 and 3 illustrate conditions prior to an explosion and the effects of the positive pressure phase.

The Negative Pressure Phase. At the instant of detonation when the positive pressure wave is formed, it begins to push the surrounding air away from the point of detonation. This outward compressing and pushing of air forms a partial vacuum at the point of detonation so that when the pressure wave finally dwindles to nothing, a broad partial vacuum exists in the area surrounding the point of detonation. This partial vacuum causes the compressed and displaced atmosphere to reverse its movement and rush inward to fill the void. This reaction of the partial vacuum and the reverse movement of the air is known as the negative or suction phase.

The displaced air rushing back toward the point of detonation has mass and power, and although this air is not moving nearly as fast inward as the pressure wave was moving outward, it still has great velocity. If the force of a positive pressure wave can be compared to a cyclone, then the negative pressure wave is comparable to a strong gale. This inward rush of displaced air will strike and move objects in its path as shown in figure 4. When it strikes the brick garden wall, it causes additional portions of the already shattered and violently battered wall to topple, but this time in a

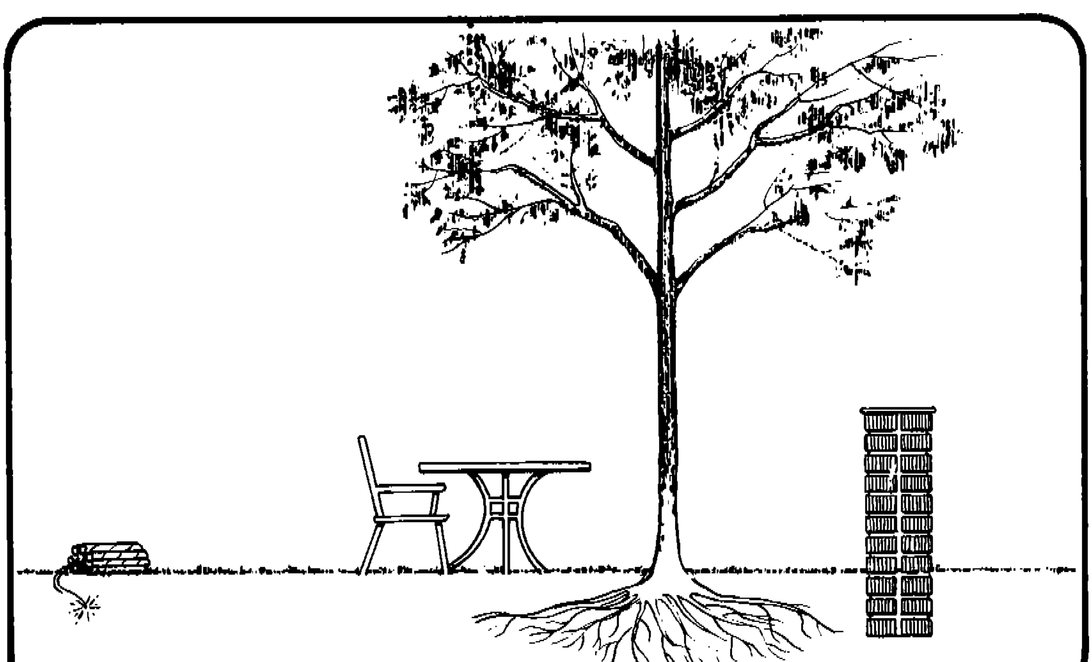

Figure 2
CONDITIONS PRIOR TO EXPLOSION

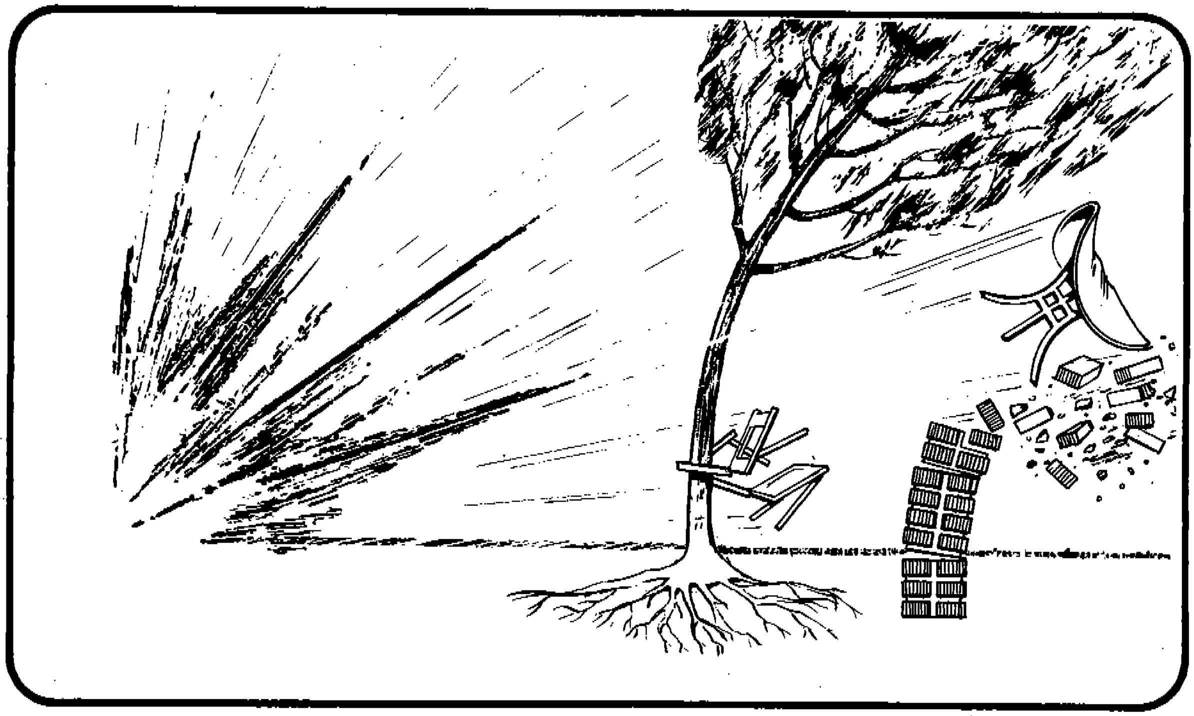

Figure 3
POSITIVE PRESSURE PHASE OF AN EXPLOSION

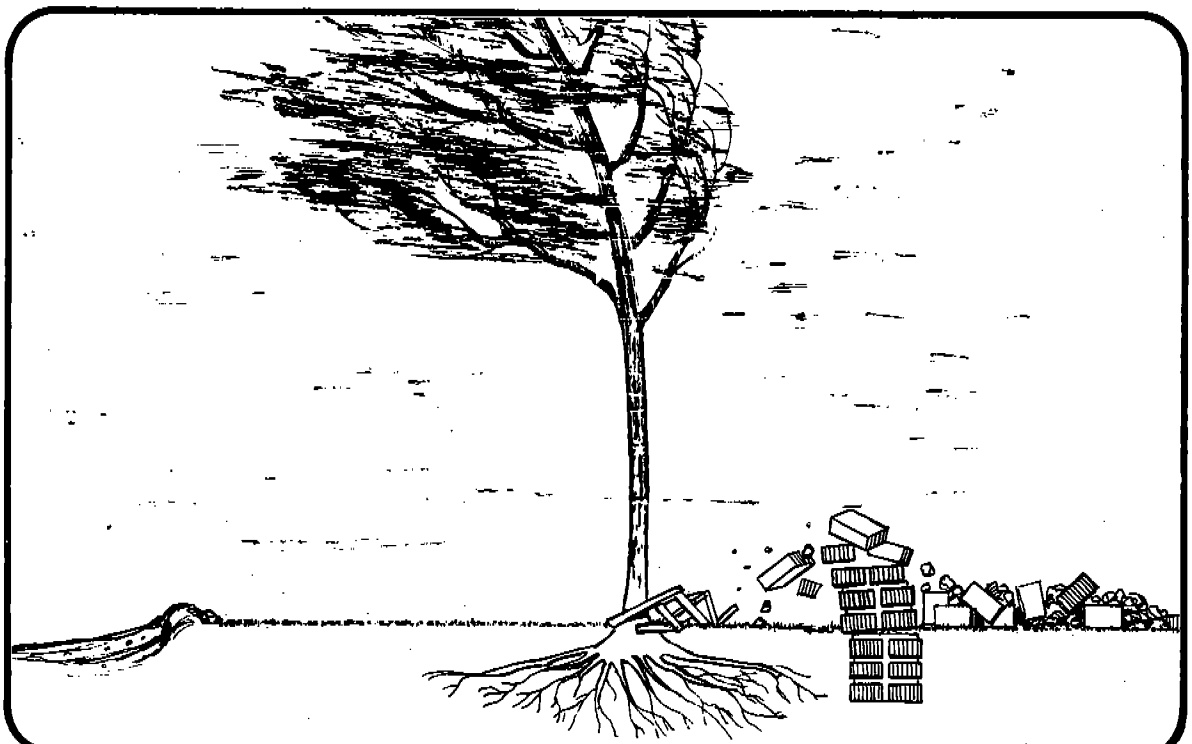

Figure 4
NEGATIVE PRESSURE PHASE OF AN EXPLOSION

direction toward the point of detonation. Figure 5 illustrates the conditions when all explosive effects have ceased.

The negative phase is less powerful, but lasts three times as long as the positive phase. This relationship is illustrated in figure 6. 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, if a block of explosive is detonated in the open, the blast wave will dissipate at a distance of 100 feet 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 200 feet 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 are focused and directed into a microphone by the TV soundman along the sidelines at a football game, enabling the home viewer to listen in as the quarterback calls signals.

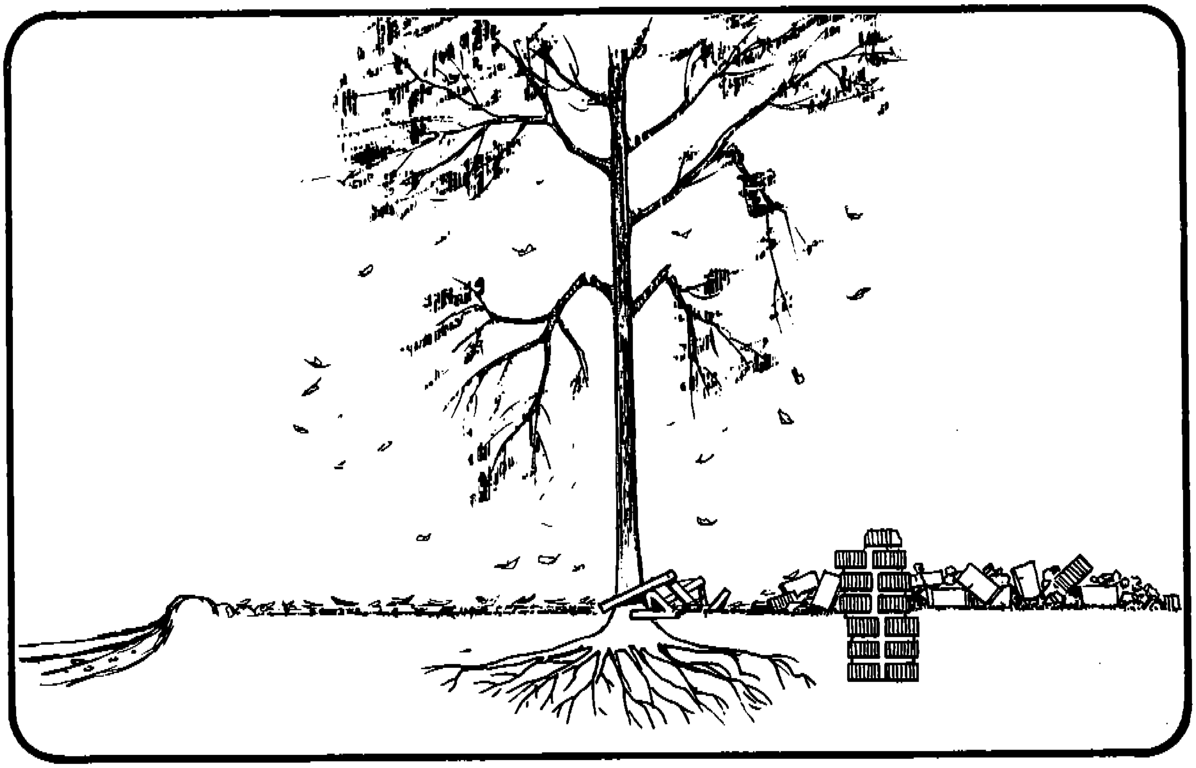

Figure 5
CONDITIONS AFTER AN EXPLOSION

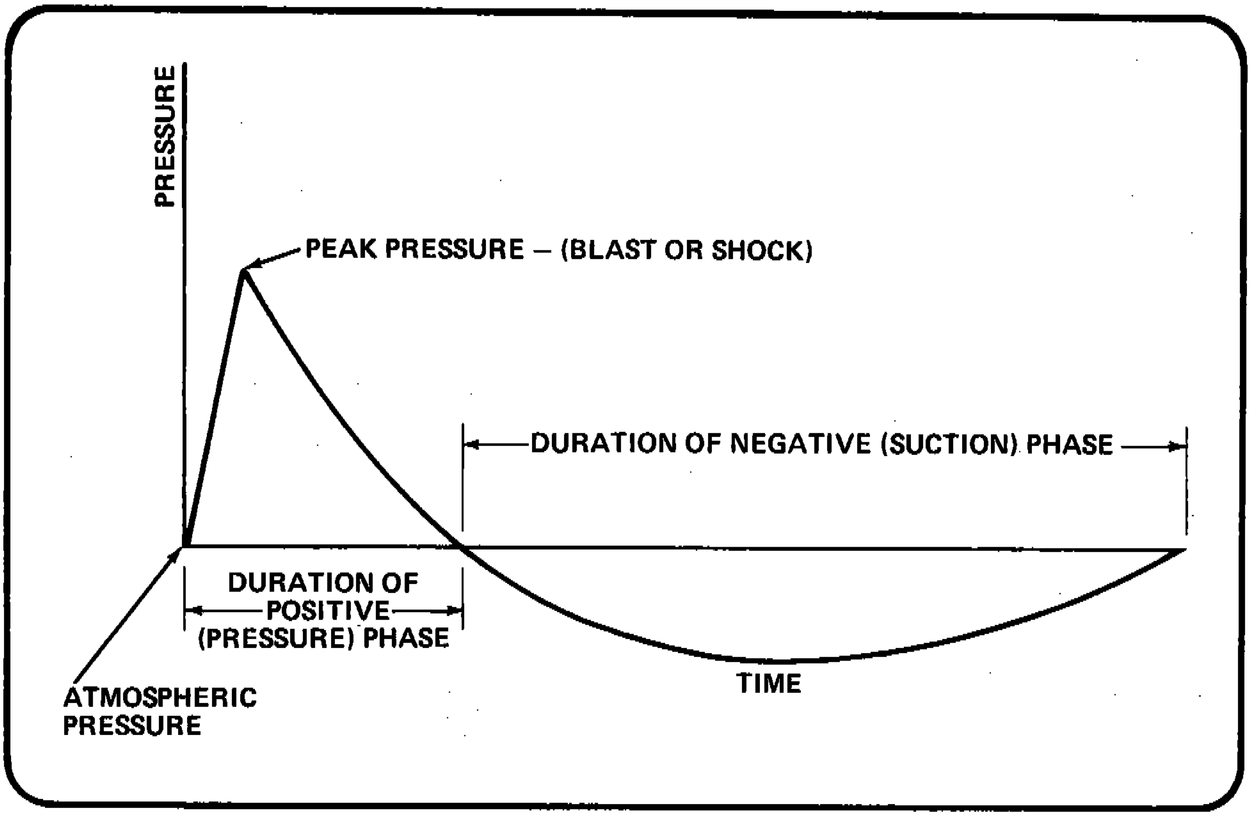

Figure 6
TIME PHASES OF A BLAST WAVE

Shielding occurs when the blast pressure wave strikes an immovable object in its path. If a square, solid concrete post two feet thick is placed in the path of the blast pressure wave and a fine 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 uncracked. Explosive waves may also be reflected at great distances and even over natural obstacles, such as hills, by bouncing off low clouds or overcast skies. Under these conditions a 50-pound charge could break windows 5 miles from the point of detonation.

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 compressable at all, the detonation will seem less violent, but actually 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 or 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. The entire building is shocked from top to bottom. Walls crack, doors jam, objects fall from the shelves, and windows shatter. Below ground in basement areas a strong shock wave may buckle walls inward, rupture water pipes and heave even concrete floors upward.

For example, if a 50-pound explosive charge is buried 10 feet in the ground and detonated, cast iron pipes 30 feet away will probably be cracked or broken, brick, tile, and concrete sewers 40 feet away would be cracked and broken; damage to building foundations can be anticipated for 50 feet and beyond.

An explosive charge detonated underwater will produce damage at even greater distances because, unlike earth, water is not compressable. Water cannot be compressed and, thus, absorb energy, so it transmits the shock wave much faster and farther and consequently produces greater damage within a larger area.

Secondary Blast Pressure Effects: Structural Fires. When an explosion occurs inside a building a fire often results. Generally, the structural fire originates not from the detonation of the explosive, but from broken and shorted electrical circuits or ruptured natural gas or fuel oil lines. Any shattered and broken debris also contribute fuel to the fire. Fires of this nature are regarded as a secondary effect of the detonation.

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, as illustrated in figure 7. 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 (2,700 feet per second) 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 before it ruptures and breaks into fragments. Approximately half of 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 which are larger in size than those resulting from a high explosive detonation and they would not have a stretched and thinned configuration. Typical low explosive filled pipe bomb fragments are illustrated in figure 8.

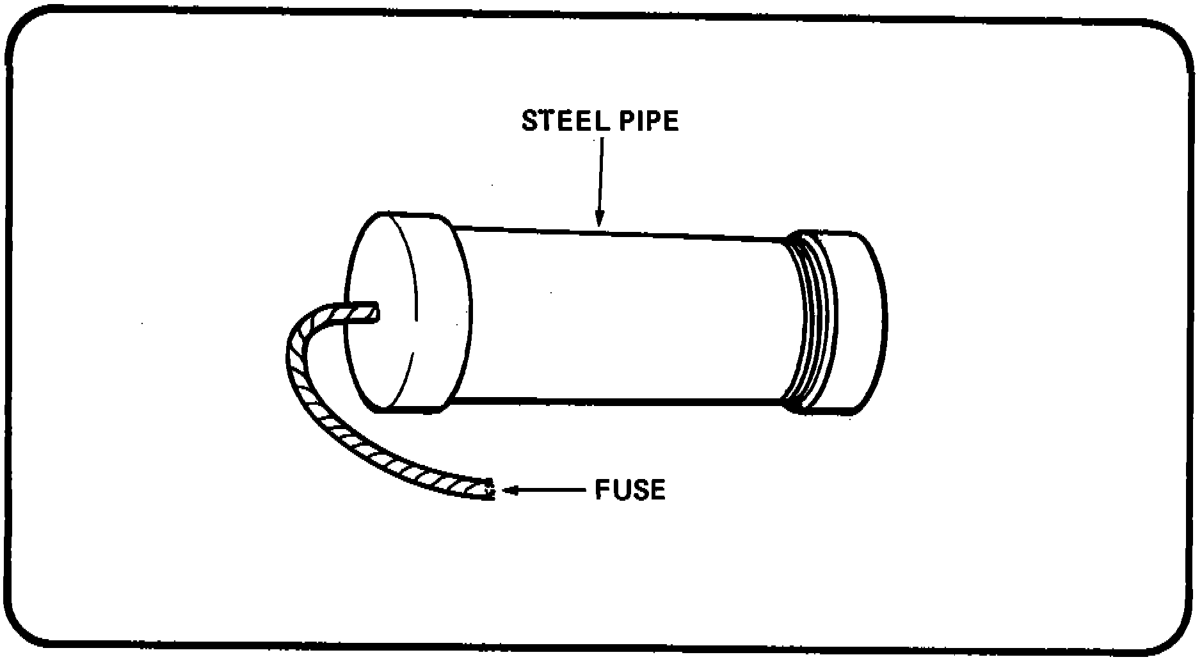

Figure 7
PIPE BOMB

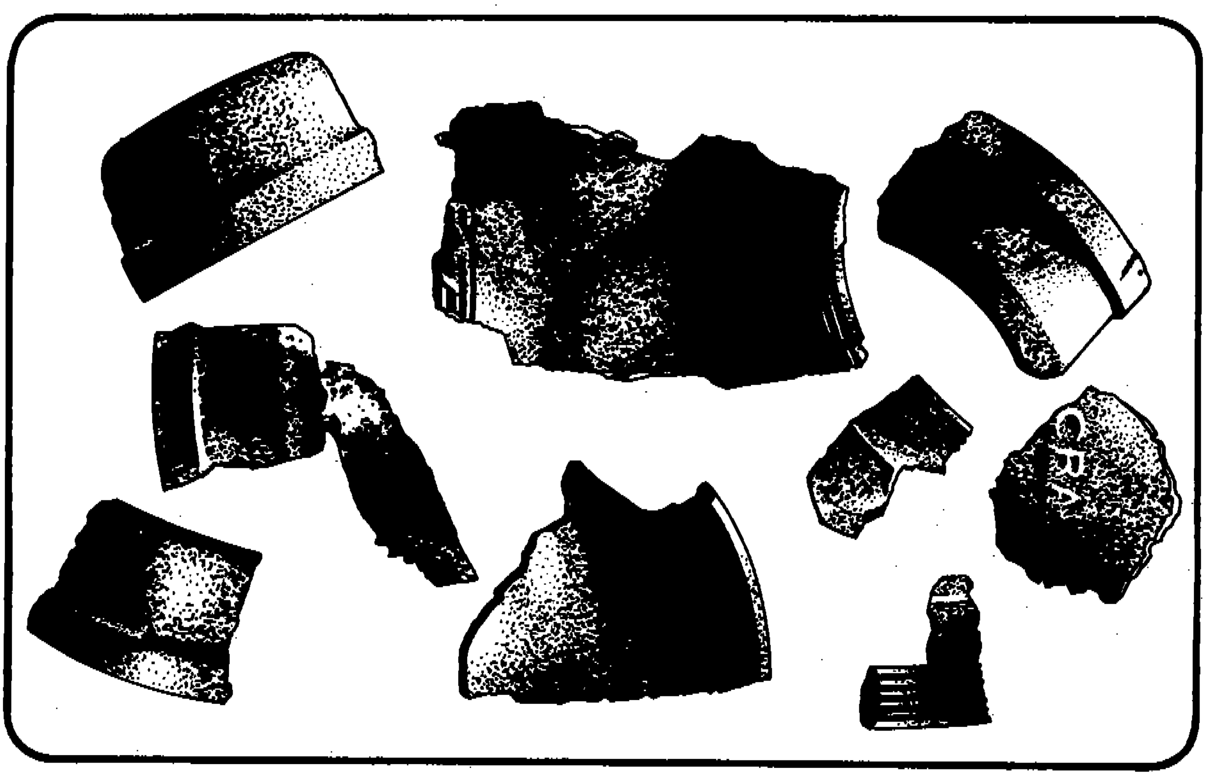

Figure 8
PIPE BOMB FRAGMENTS

Occasionally, "chunks" of a pipe bomb will be recovered. If the bomb casing containing either a high or low explosive has been precut or serrated with deep grooves, which normally cross each other, then the fragments produced will have a rather uniform size, shape, and weight. This technique of grooving which is known as serration or pre-engraving is illustrated, as applied to hand grenades, in figure 9.

Whereas fragments are pieces of the bomb casing which are formed when it ruptures, 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 have been normally expended in fracturing the bomb casing into fragments, is used instead in propelling the performed, separate pieces of shrapnel. A bomb employing shrapnel is illustrated in figure 10. Consequently, the use of shrapnel inside or attached outside a bomb results in an increase in blast damage as well as the projection of the shrapnel. Fragmentation and shrapnel produce damage by cutting, slicing, or punching holes in materials in the vicinity of the point of detonation.

Secondary Fragmentation Effect: Fire. The heat of fragments produced by the detonation of a high explosive bomb may cause secondary fires. This heat is induced at the instant of detonation and compounded by the stretching and tearing action of the detonation as well as by air friction

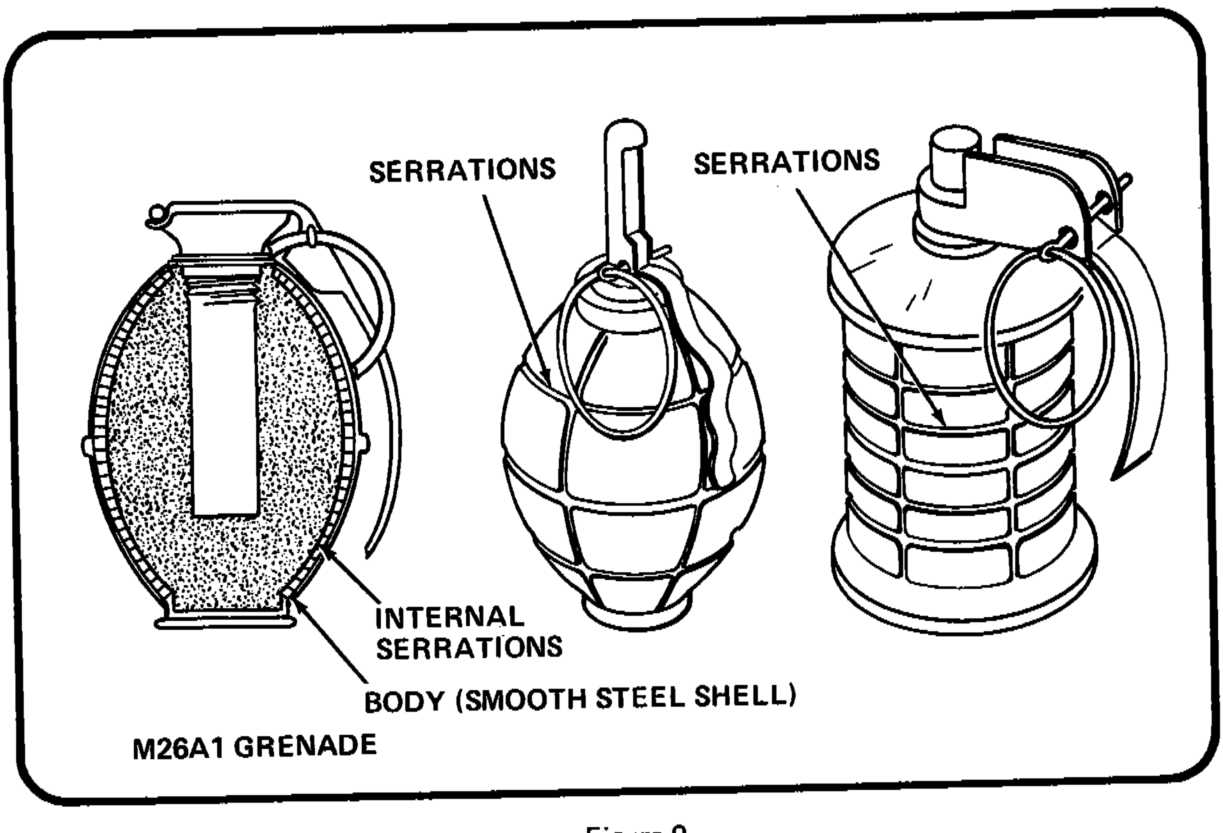

Figure 9
SERRATION OR PRE-ENGRAVING OF EXPLOSIVE DEVICES

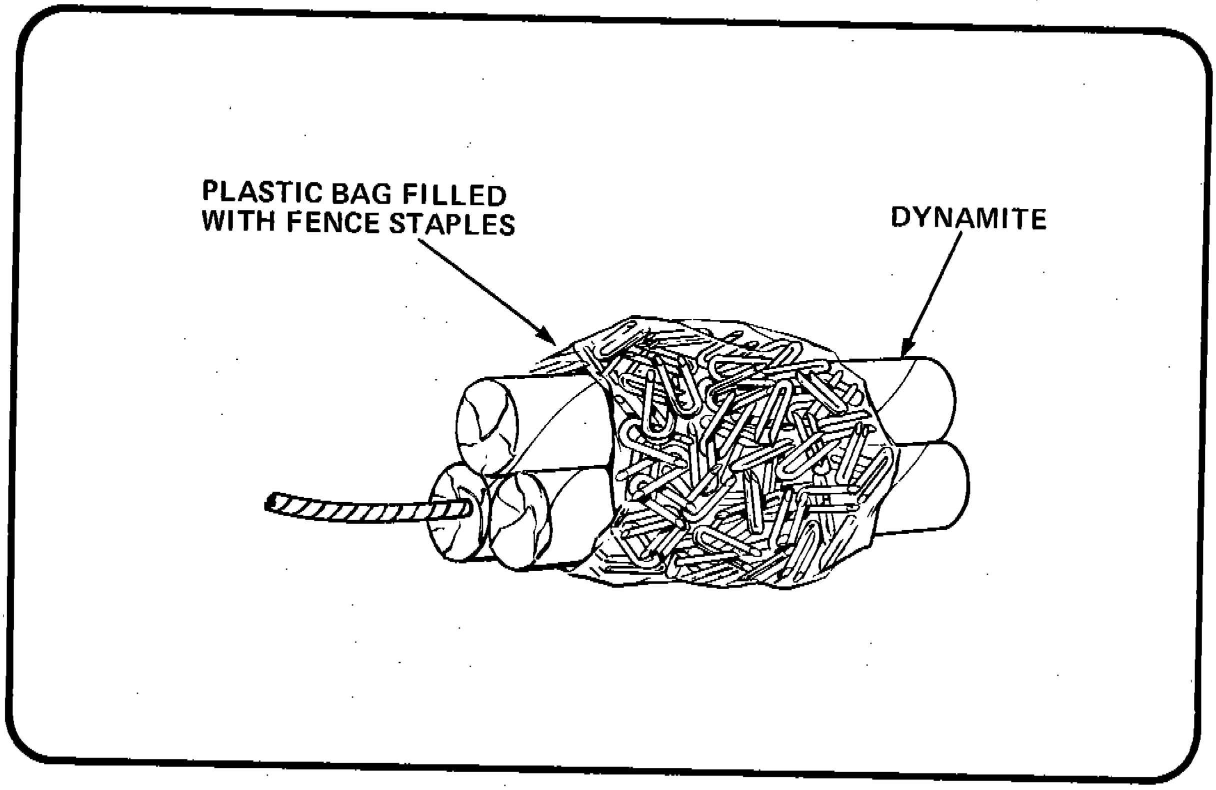

Figure 10
SHRAPNEL USED WITH HIGH EXPLOSIVE BOMB

and impact friction. The red hot fragments may, for example, puncture an automobile fuel tank and ignite the gasoline, imbed themselves in combustible material and cause ignition, or start grass fires a distance of ½ mile from the point of detonation.

Incendiary Thermal Effect

The incendiary thermal effect produced by the detonation of a high or a 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 the 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 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 starts, 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.

SECTION TWO

EXPLOSIVES

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 contain 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 exploding substances, as contrasted to detonating substances, the combustible and oxidizer are blended mechanically. When making black powder for example, the charcoal, sulfur, and niter are first separately ground into fine powder and then mechanically mixed together. The result of this type of blending is known as an explosive mixture. Mechanical blending is generally used when manufacturing a class of explosives known as low explosives or propellants such as pistol and rifle powders. 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 union 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 in the closest possible union. All high explosives, in contrast with low explosives, are composed of chemical compounds consisting of tightly bonded combustibles and oxidizers.

Classification by Velocity

The classification of explosives by the rate of 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 3,280 feet per second (f.p.s.). For example, black powder has a rate of approximately 1,312 f.p.s. Low explosives are used primarily as propellants, because a mechanically mixed explosive charge reduces to a minimum 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 the 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. Pipe bombs containing low explosives are commonly used by violent revolutionary groups and other criminals, because the component ingredients are easily acquired and they are simple to construct and initiate.

High Explosives. This type of explosive is designed to shatter and destroy. The detonation rate of high explosives is above 3,280 feet per second. There is a wide range in the detonation velocities of high explosives, extending from some dynamites at 9,000 feet per second up to RDX at 27,500 feet per second.

High explosives differ from low explosives in that they must, in general, be intiated 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 "explosion" 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 apparently 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 detonate, and the detonation 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* and is usually expressed in feet or meters per second.

Explosive Work

The varying velocities of explosives have a direct relationship to the type of work they can perform. The difference in velocity determines 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 he wishes it to perform. 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 (1,312 f.p.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 break up or reduce the boulder to rubble so that it may be removed, he might place a TNT (23,000 f.p.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 as illustrated in figure 11. 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 relationship is illustrated in figure 12.

This improved effectiveness is caused by the focusing of the hot gases released by the detonating explosive. The extremely hot, swiftly moving spit of concentrated power is called the "jet" and performs in much the same manner as the white-hot flame of a cutting torch. Figure 13 is a step-by-step illustration of how this jet is formed.

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.

Certain factors affect the efficiency and functioning of shaped charges. The angle of the walls of the cone of the shaped charge determines the speed and density of the jet. This *cone angle* is generally between 30 to 80 degrees. The jet formed by the shaped charge requires some degree of air space to properly form. In order to increase the efficiency of the shaped charge, it is usually placed a short distance from the material to be cut. This distance is referred to as a *standoff distance* and is usually 1½ times the cone diameter. Thus, if the diameter of the shaped charge cone is 2 inches, the *standoff* should be approximately 3 inches.

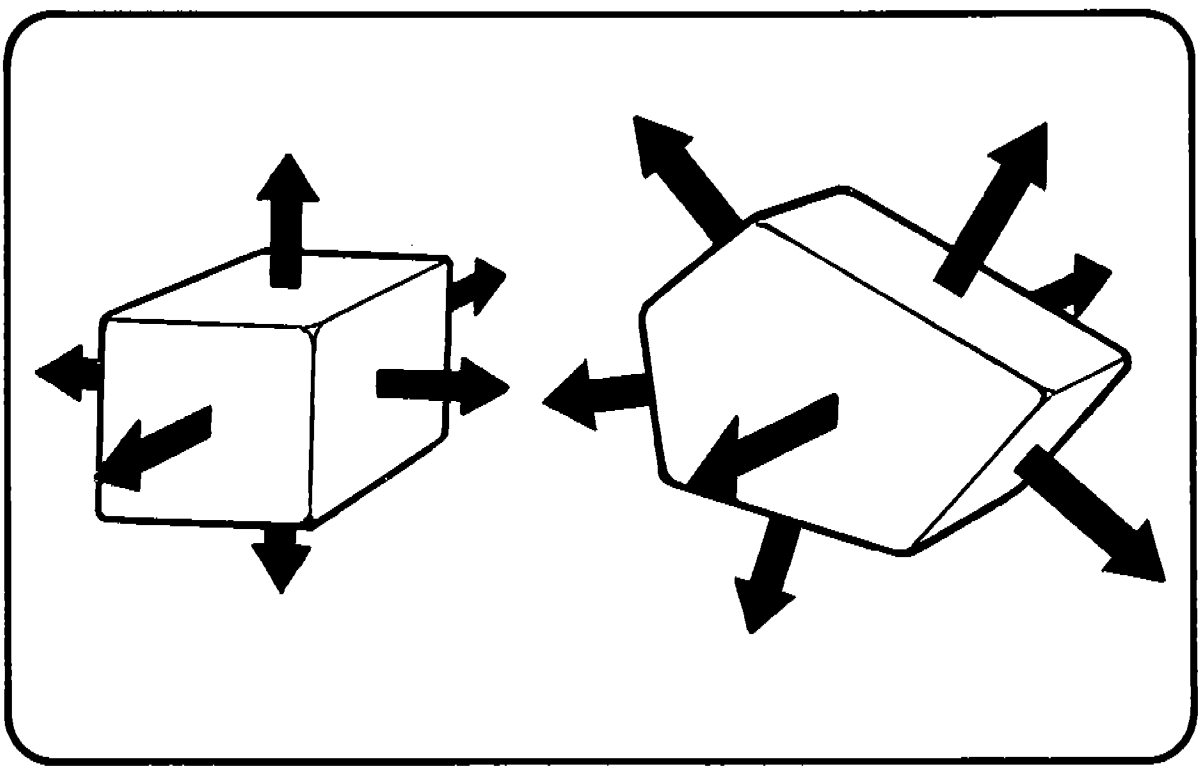

Figure 11
RESULTING DIRECTIONAL EXPLOSIVE FORCES

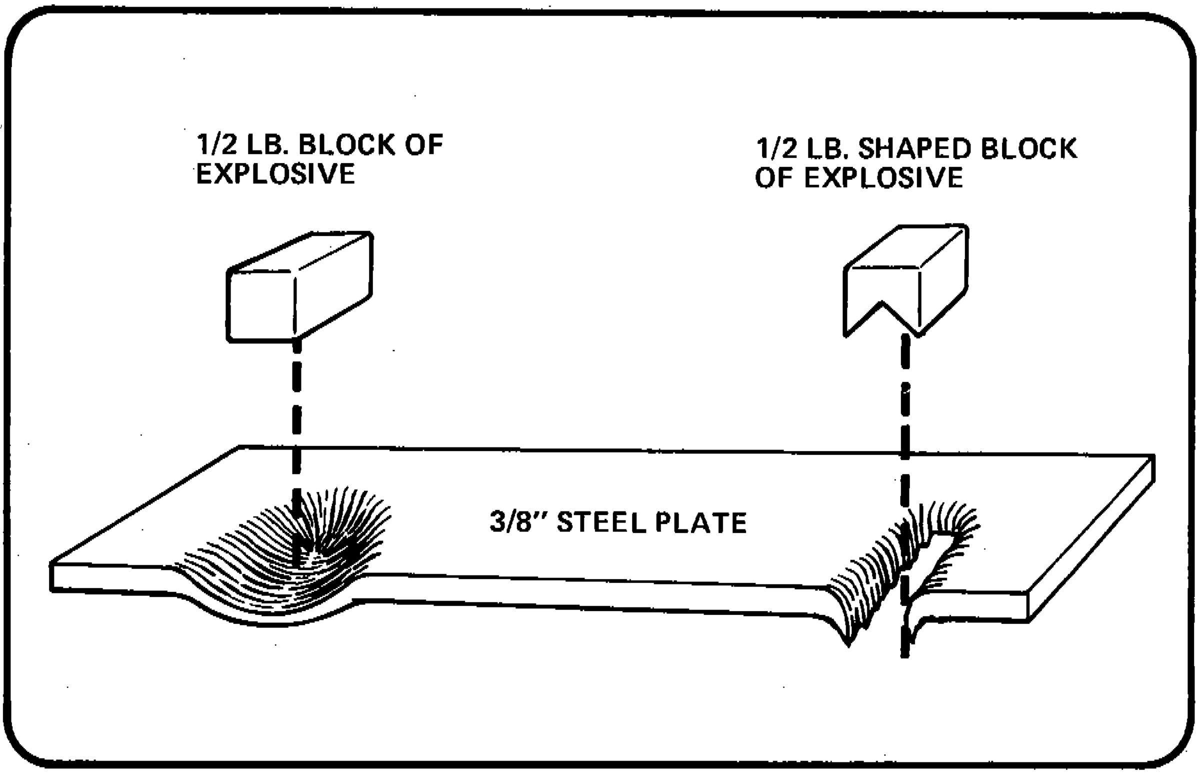

Figure 12
INCREASED EFFECT OF SHAPED EXPLOSIVE

The cone of the shaped charge may be lined with materials such as steel, copper, or glass. These *cone liners* control, to some extent, the cutting ability of the charge by adding to the jet the fine particles of the cone liner, raising the temperature of the jet and providing abrasive materials to assist in cutting the target material.

There are two basic types of shaped charges, the *conical shaped charge* and the *linear shaped charge,* which are illustrated in figure 14. 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 artillery 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. Figures 15 and 16 illustrate a conical shaped charge manufactured by DuPont, which is used to tap a hole in an open hearth steel furnace and allow the molten steel to be obtained. Other conical shaped charges are used to perforate oil well casings so that more oil flows into the collection tube.

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

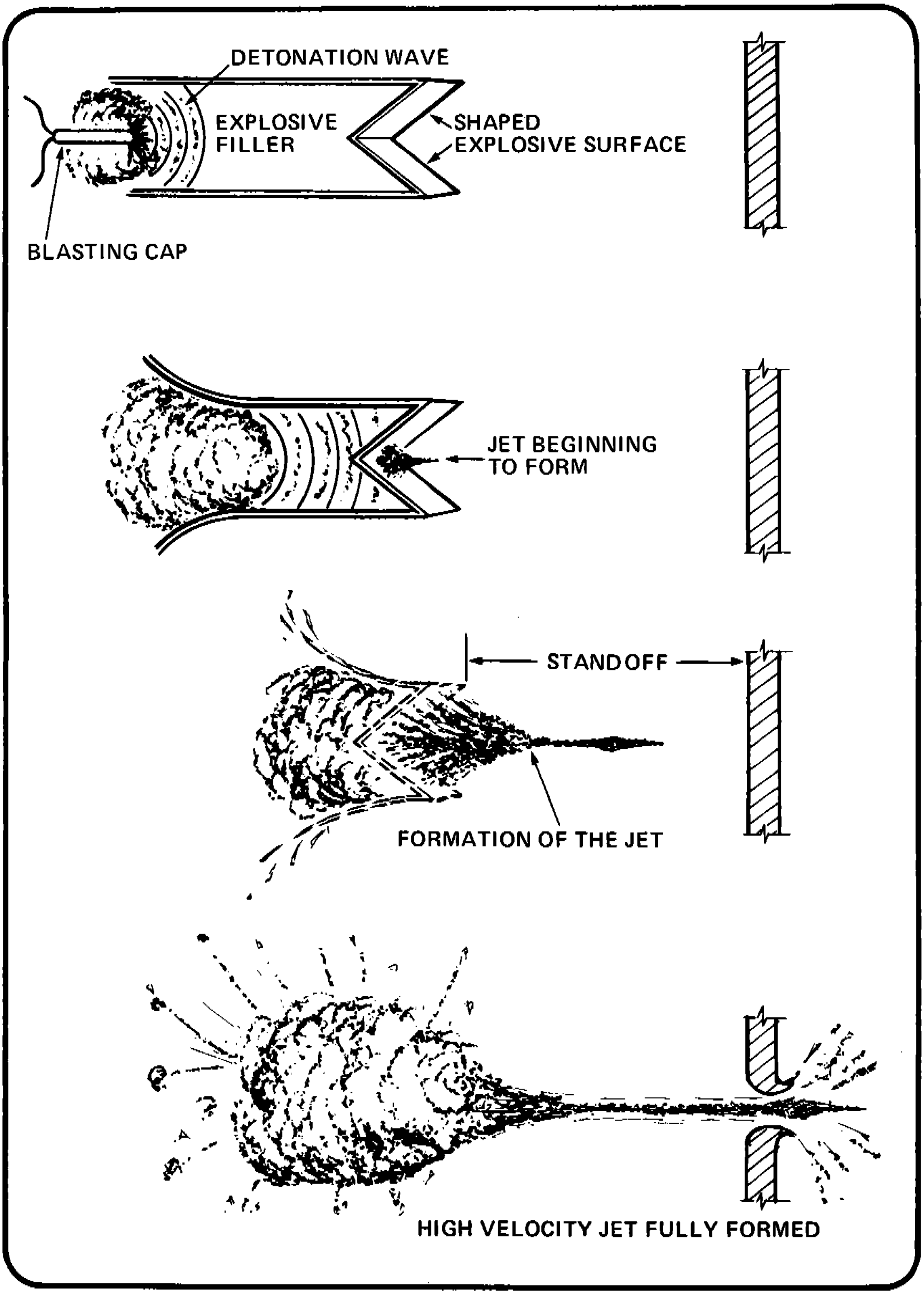

Figure 13
SHAPED CHANGE JET FORMATION

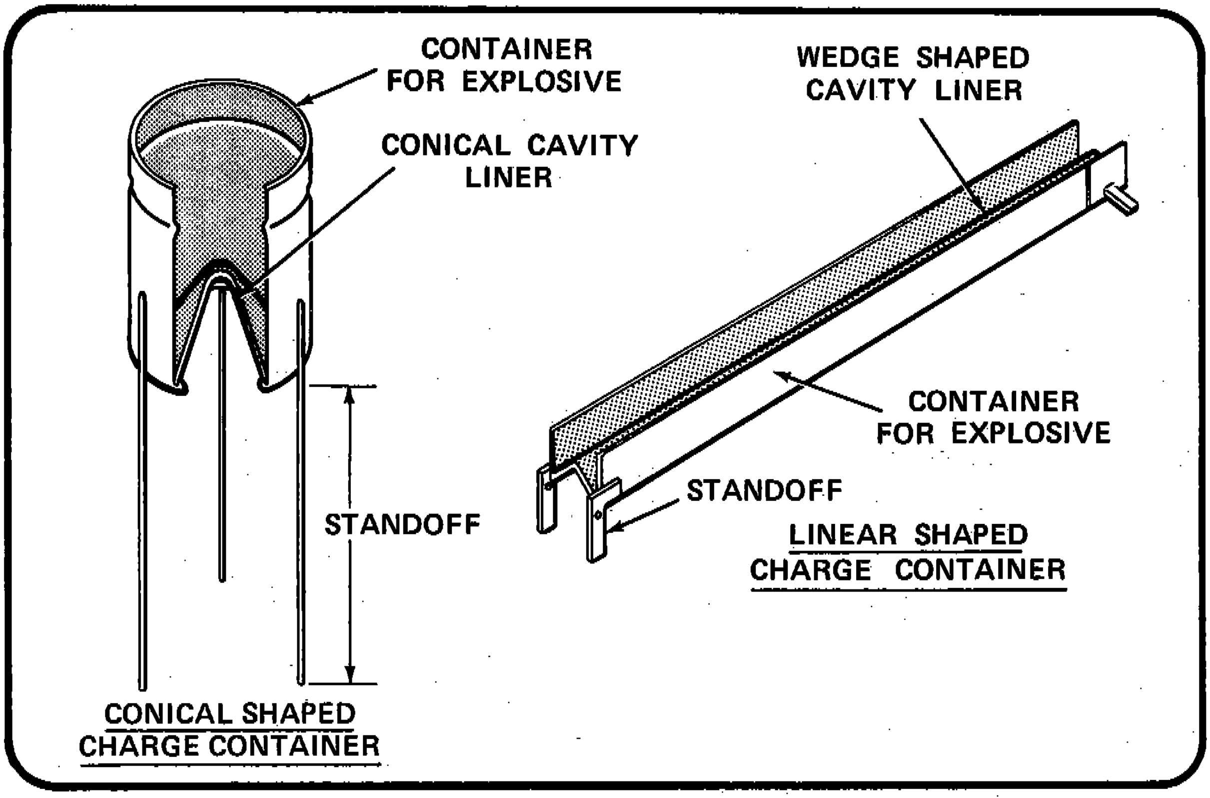

Figure 14
SHAPED CHARGE CONTAINERS

charge contained in a polystrene box. The box is placed against the target and the shaped charge is detonated, providing an entry hole to the building. This linear shaped charge device is illustrated in figures 17 and 18.

Two different sizes of prepackaged shaped charges are utilized by the armed forces in demolition and breeching operations against steel or reinforced concrete structures. The 15-pound M2A3 shaped charge, shown in figure 19, contains 12 pounds of a 50/50 pentolite/composition B mixture. It is almost 15 inches in height and 7 inches in diameter. The body is made of fiberboard painted olive drab in color. Attached to the shaped charge is a pressed fiber cylindrical standoff. There is a threaded blasting cap well at the upper end. The cone angle is 60 degrees and the cone liner is made of high density glass. This shaped charge is designed for front line demolition of pill boxes and reinforced concrete bunkers. When detonated, the M2A3 will penetrate armor plate to approximately 12 inches or reinforced concrete to a depth of 34 inches. The hole produced will be approximately 3½ inches in diameter tapering to 2 inches. The glass cone liner results in a "cold hole," allowing other explosives to be hand packed into the opening immediately without danger of excessive heat.

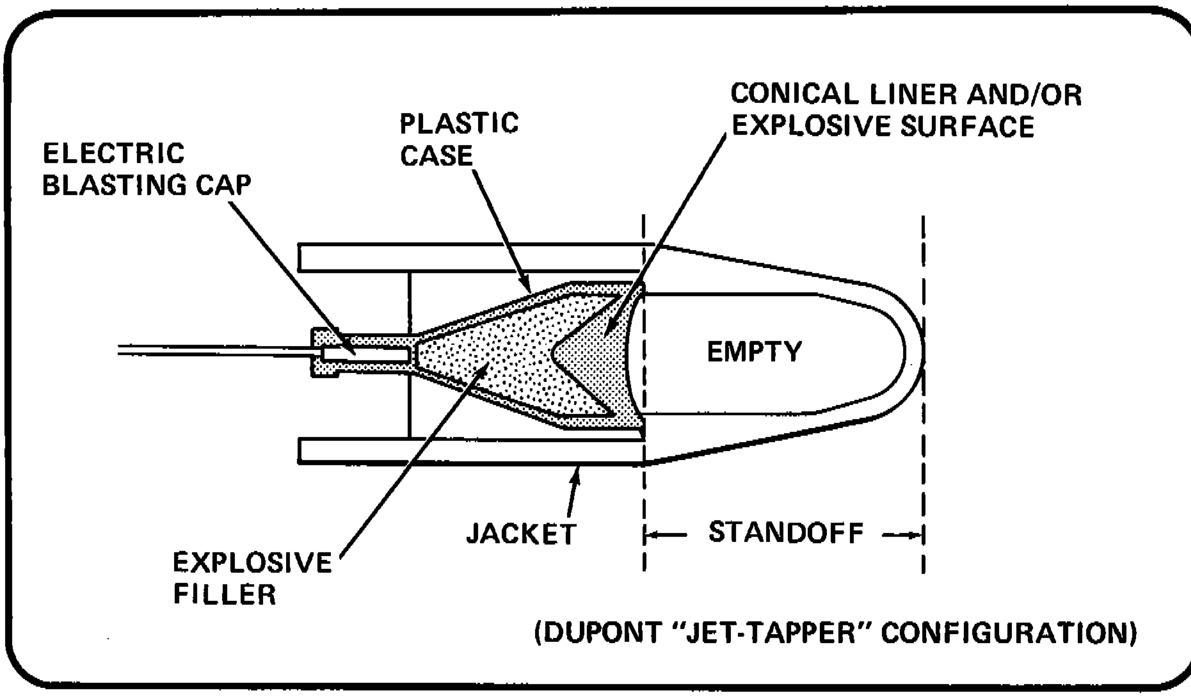

Figure 15
A TYPE OF COMMERCIAL CONICAL SHAPED CHARGE

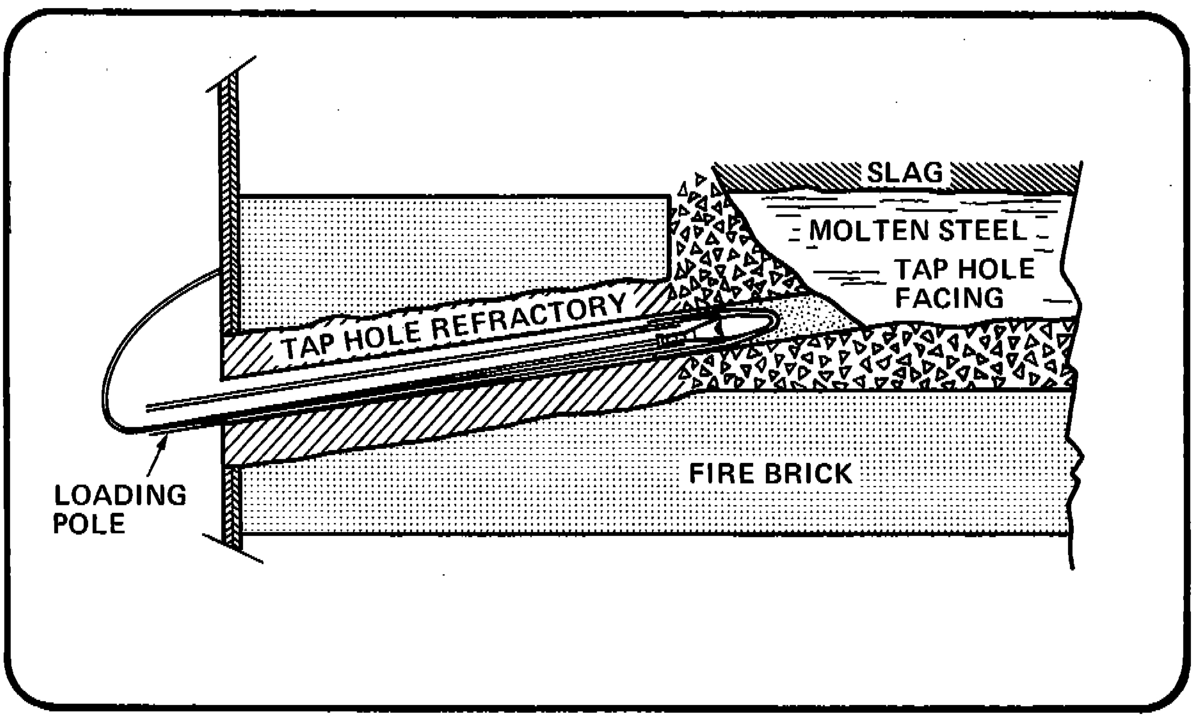

Figure 16
CROSS SECTION OF OPEN HEARTH FURNACE TAP HOLE
SHOWING JET TAPPER IN POSITION FOR FIRING

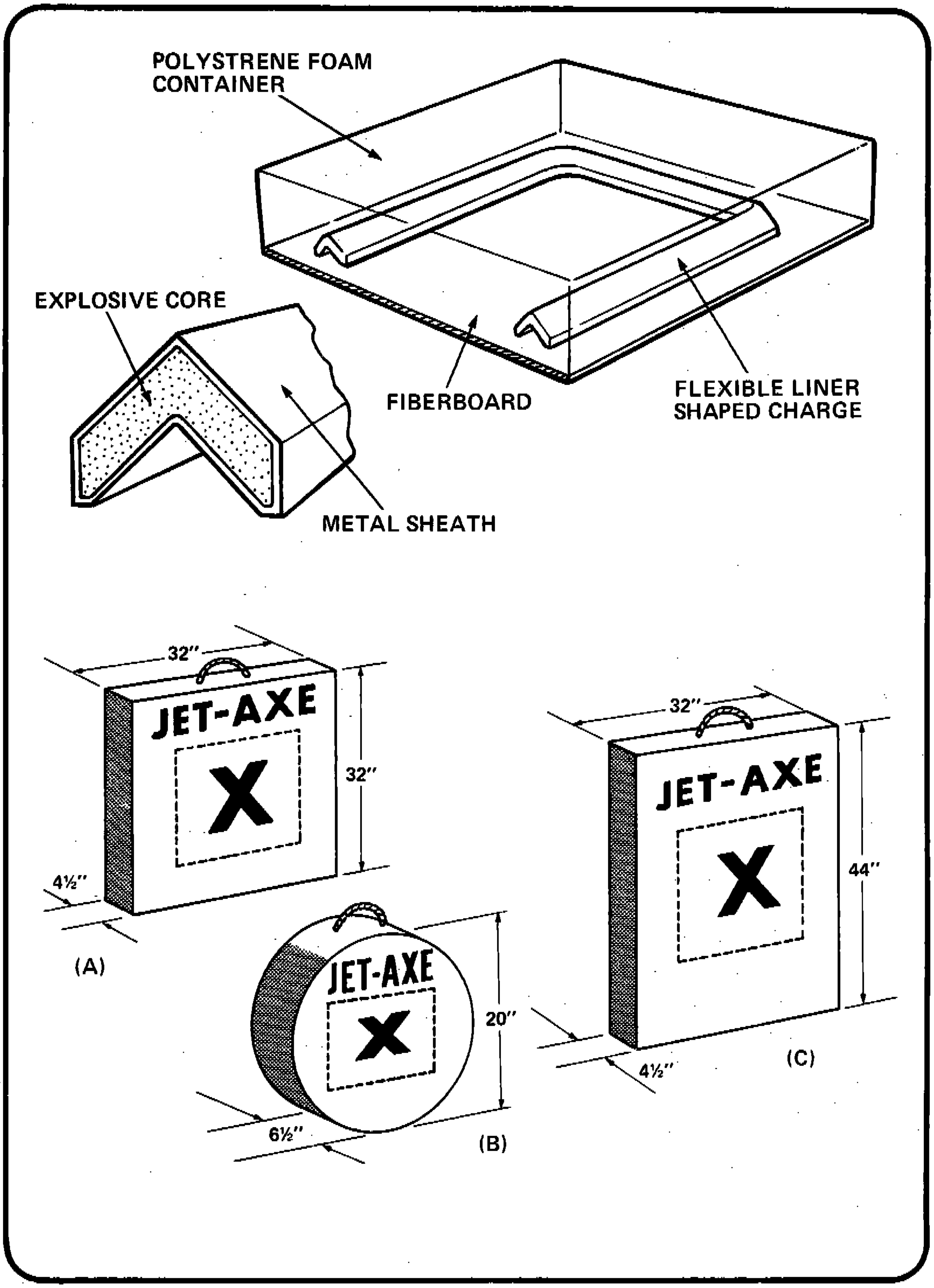

Figure 17
CONFIGURATION AND CONTAINERS OF
JET-AXE LINEAR SHAPED CHARGE

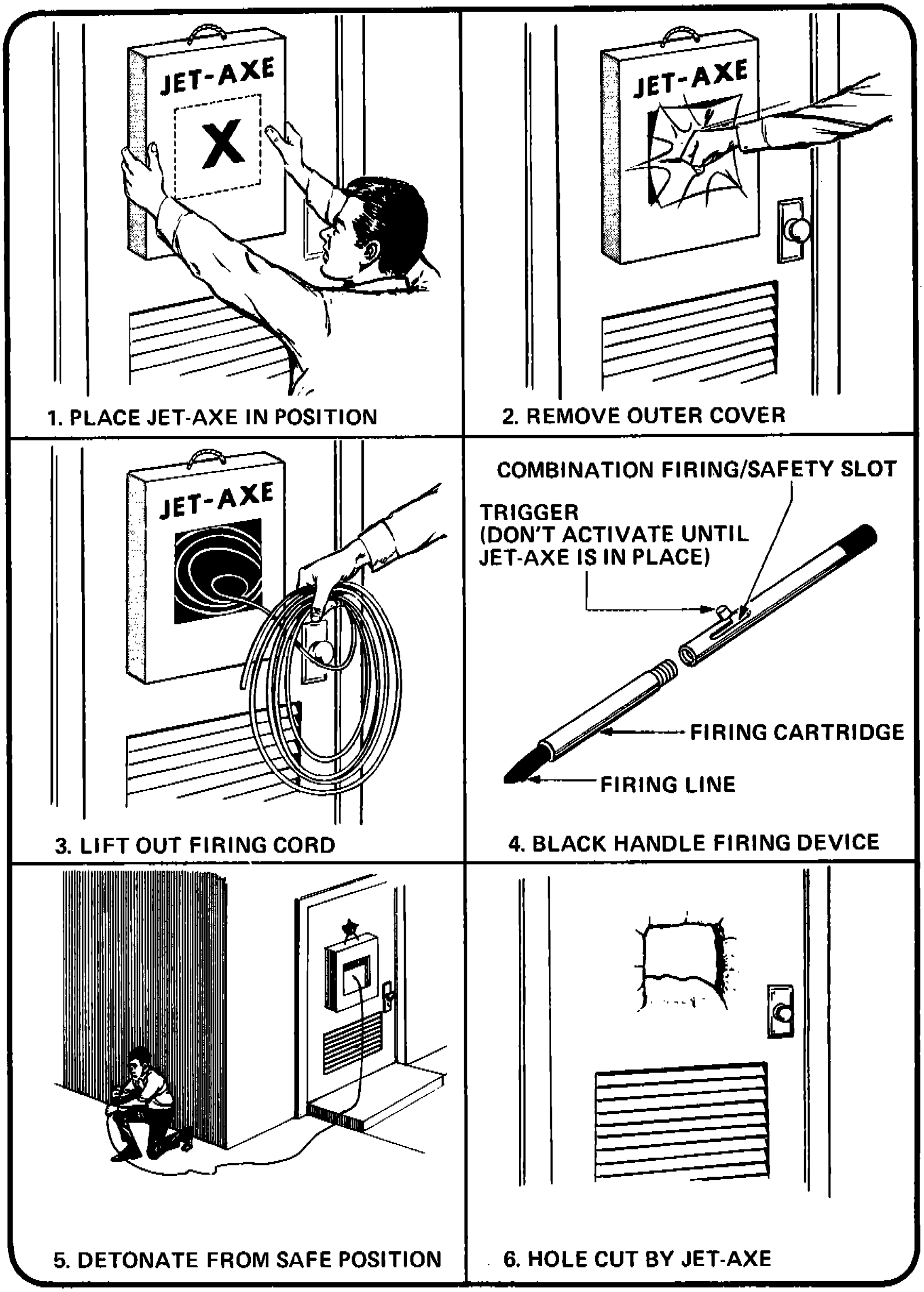

Figure 18
EMPLOYMENT OF JET-AXE

The other military prepacked shaped charge is the 40-pound, M3 shaped charge, illustrated in figure 19, which contains 30 pounds of 50/50 pentolite/composition B. This shaped charge is 15½ inches in height and 9 inches in diameter. A 15-inch metal tripod is employed to provide the correct standoff. There is a threaded blasting cap well at the upper end. The cone angle is 60 degrees and the cone liner is drawn steel. When detonated, the 40-pound shaped charge will penetrate armor plate to approximately 20 inches and reinforced concrete to a depth of approximately 62 inches. The shaped charge hole will be approximately 5 inches in diameter tapering to 3½ inches. The steel cone liner produces a "hot hole," and a cooling time must be observed before explosives may be safely loaded into the cavity produced. The 40-pound shaped charge is used to reduce very heavily reinforced fortifications. 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.

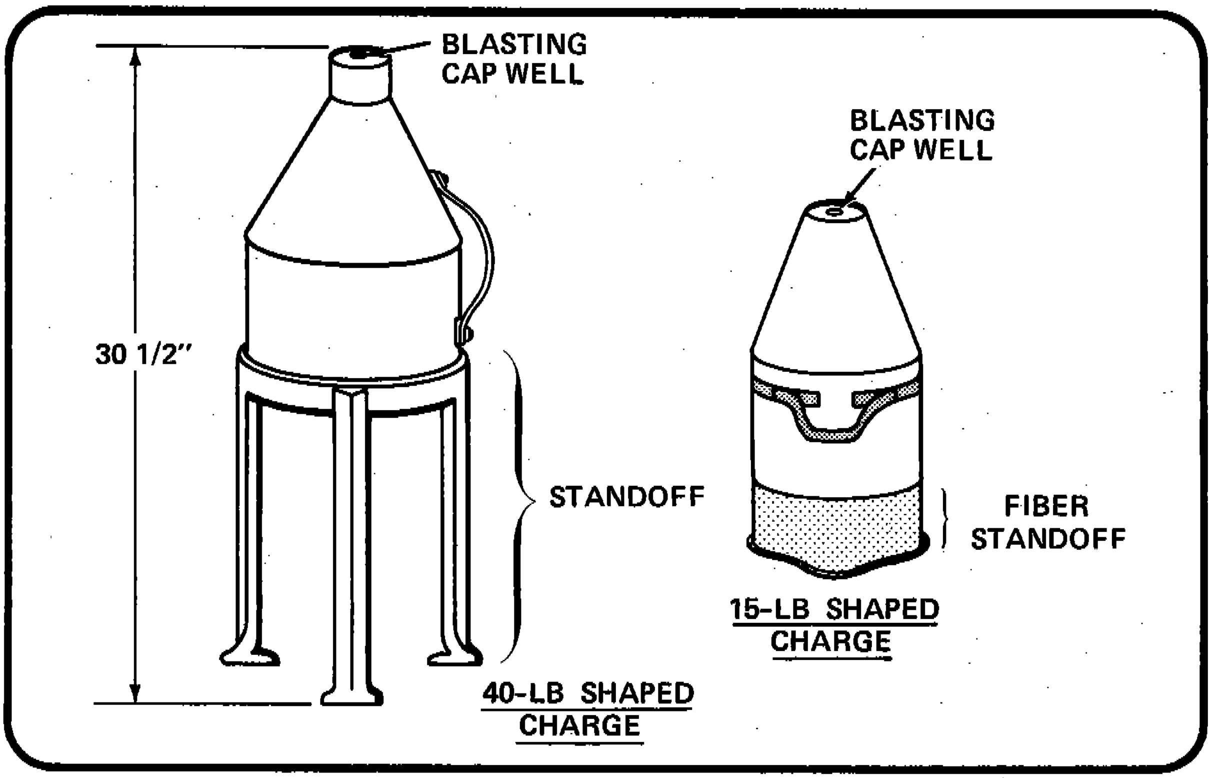

Figure 19
STANDARD MILITARY SHAPED CHARGES

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 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 (propellants), 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 is ignited with a match by the bomber. 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 a wide 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 velocity, the primary high explosives are able to create an extremely powerful detonation wave 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 fuzes the primary high explosive is usually initiated by shock of impact or heat producing friction. The more commonly used primary high explosives are RDX, lead styphnate, lead azide, and mercury fulminate, which have detonation velocities ranging from 27,500 f.p.s. for RDX to 16,500 f.p.s. for mercury fulminate.

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 9,000 f.p.s. for some dynamites to 26,000 f.p.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. This three-step high explosive train is shown schematically in figure 20.

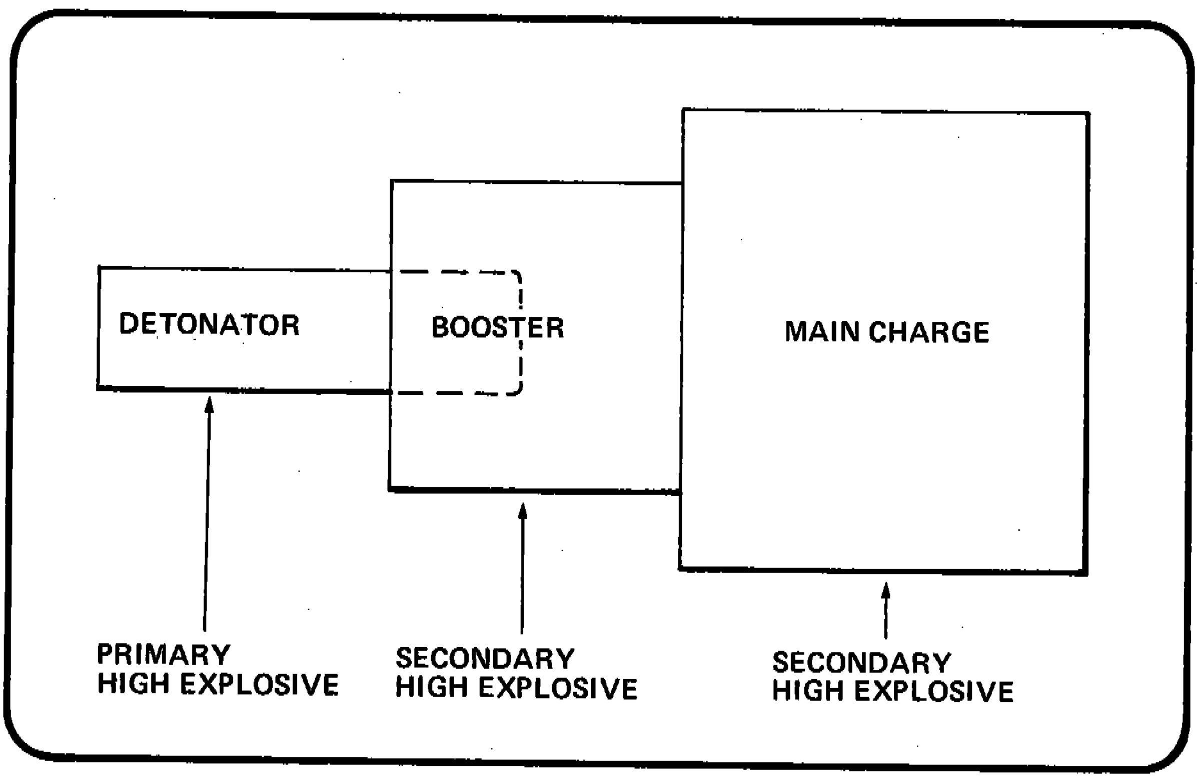

Figure 20
BASIC THREE-STEP EXPLOSIVE TRAIN

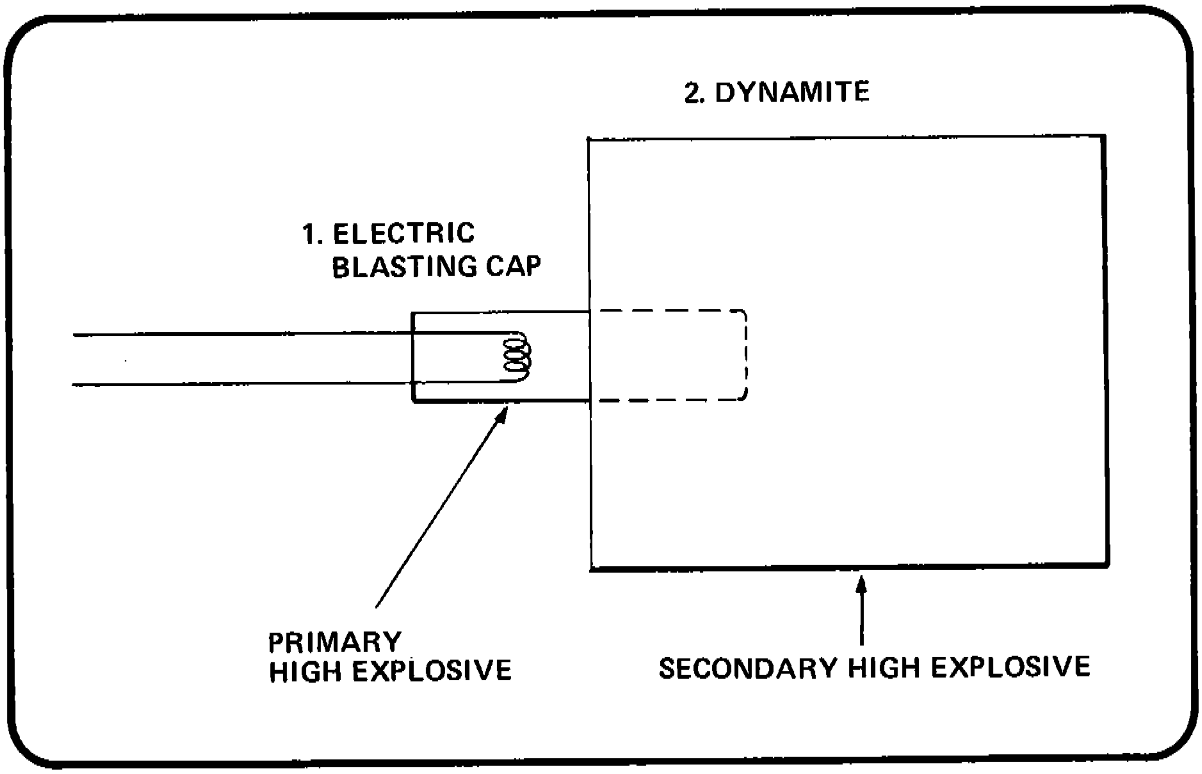

Figure 21
TWO-STEP EXPLOSIVE TRAIN

Typical High Explosive Trains. The explosive train normally used in work with high explosives is a two or three-step train. For example, to remove a tree stump from the ground a simple two-step train might be employed. An electric blasting cap, a primary high explosive, and a stick of dynamite, a secondary high explosive, would be combined as illustrated in figure 21. The blasting cap would be 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.

The same stump removal work could also be accomplished with a simple three step explosive train. A length of safety fuse filled with black powder, a nonelectric blasting cap, and a stick of dynamite could be combined as illustrated in figure 22. The burning black powder, a low explosive, 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. For example, to make a large hole in the earth it is necessary to select an explosive with good earth moving characteristics, such as ammonium nitrate, which is also relatively inexpensive in bulk quantities. In fact, it may be decided to improvise an

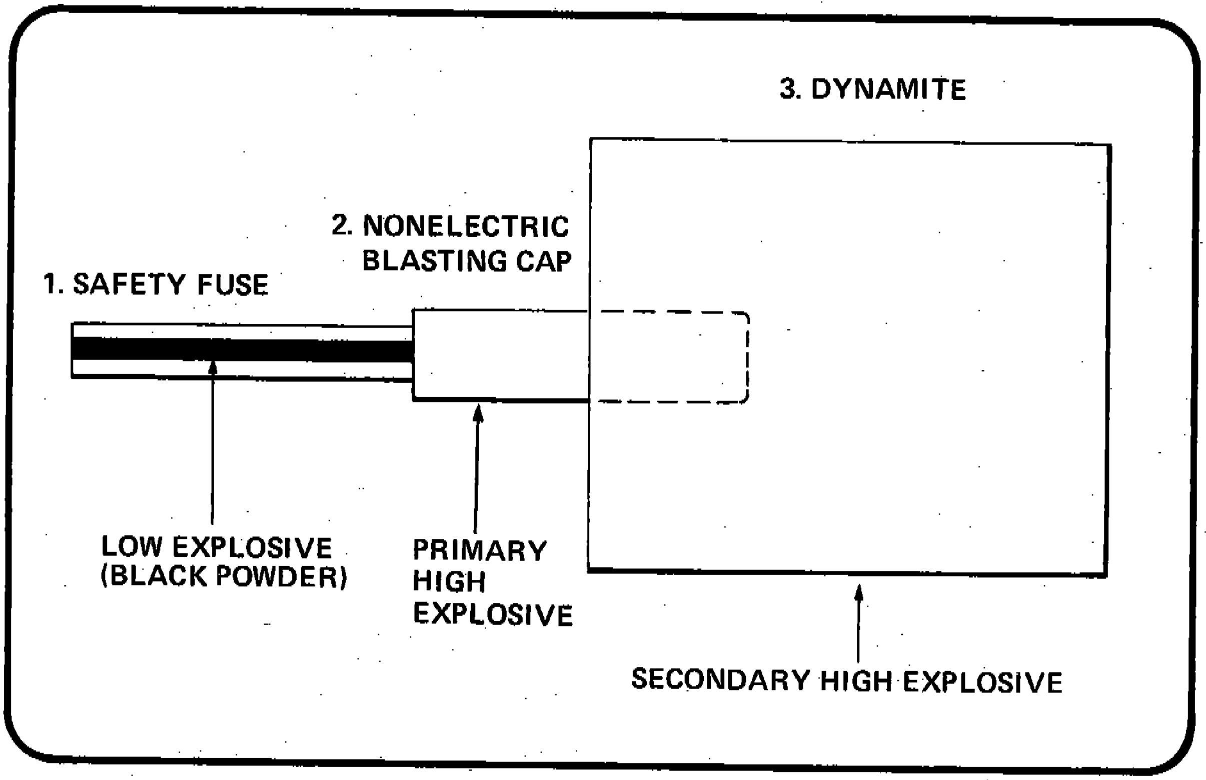

Figure 22
THREE-STEP EXPLOSIVE TRAIN

ammonium nitrate explosive by purchasing several hundred pounds of ammonium nitrate fertilizer and mixing it with common fuel oil. This mixture, known as ANFO (ammonium nitrate fuel oil), is widely used because of its low cost and accessibility

ANFO, however, is quite insensitive and a blasting cap alone will not cause it to detonate. In order to detonate ANFO a booster must be employed. Therefore, the explosive train will include a safety fuse, a nonelectric blasting cap, a dynamite booster, and ANFO as illustrated in figure 23.

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.

COMMON EXPLOSIVES

The remainder of this section will discuss some of the more common explosives likely to be encountered by public safety personnel. This general coverage will include a physical description of the explosive material and information regarding its normal use and packaging. In order to assist in

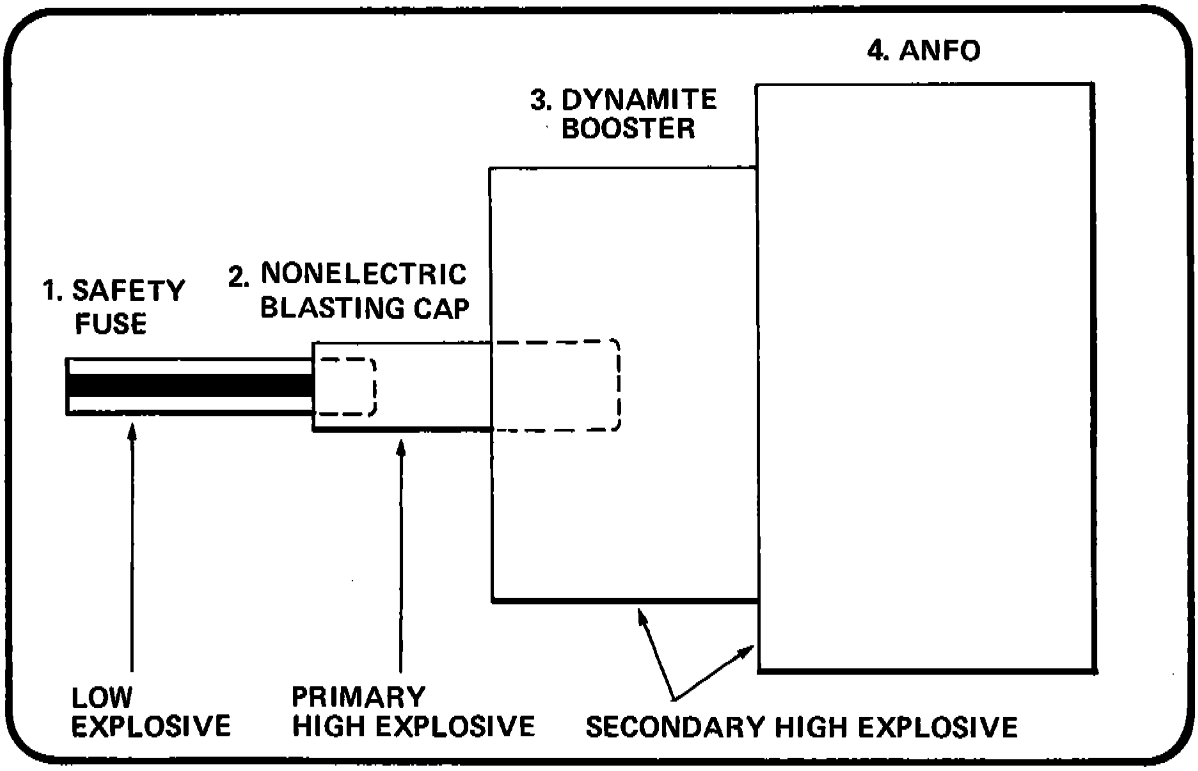

Figure 23
FOUR-STEP EXPLOSIVE TRAIN

rapid identification of explosives by their functional position in the explosive train, they will be covered under the major headings previously discussed:

- Low Explosives
- Primary High Explosives
- Secondary High Explosive Boosters
- Secondary High Explosive Main Charges

Incorporated into the major headings will be certain blasting accessories which employ or are used to detonate the explosives being discussed. While it is beyond the purpose of this publication to provide detailed technical data on explosives, certain selected technical characteristics of interest to public safety personnel are summarized in special tables at the end of the section. See figures 47-54.

Low Explosives

Black Powder. The average composition of black powder is saltpeter (potassium nitrate), 75 parts by weight; sulphur, 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 ½ inch 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. Widely used during the Civil War as a bursting charge in artillery ammunition, black powder is often encountered by public safety personnel in dealing with Civil War "souvenir" items and has been found to be dangerous and fully capable of explosion in spite of the passage of time.

Sensitivity to friction, heat, impact, and sparks makes black powder one of the most dangerous explosives to handle. It is particularly sensitive to both electric and nonelectric generated sparks and should, therefore, be handled with wooden or plastic tools. As a further precaution, the body should be grounded by touching a water pipe or other grounded object before black powder is handled. Outdoors, the body can be grounded by rubbing the hands on the ground prior to any physical contact with the powder. In any environment where black powder will be handled, clothing of static electricity producing nylon, wool, or silk should be avoided in favor of cotton fabrics.

One use for black powder is as a propellant for ammunition. It is sold in tin flasks and bulk tin containers for the use of hobbiests in hand loading ammunition or firing muzzle loading weapons. Black powder used for this purpose is irregular in grain configuration and has a shiny, metallic appearance. It is graded in grain size by the letter "F" appearing with the letter "g." For example, Fg, FFg, FFFg, and FFFFg, with the addition of each "F" indicating a finer grain. A special granulation known as A-1 is used by the military in the firing of ceremonial cannons.

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 25-pound metal kegs. For commercial blasting, black powder is also pressed into cylinders measuring 2 by 1¼ inches. Some cylinders have a 3/8-inch 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 8 inches in length and packed in 25 and 50-pound 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 that spits 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.

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 manufacture, 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 seconds per foot, while a less common type is designed to burn at the rate of 30 seconds per foot. Traditional blasting doctrine calls for the testing of safety fuse before it is employed in any field operation to determine the exact burning time.

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 initiation of a low explosive main charge. One disadvantage of using safety fuse in this way, at least from the point of view of the bomber, is that the smoke and characteristic acrid odor given off by burning safety fuse makes it detectable if employed in an occupied area. It would, therefore, more logically be used in unguarded or unoccupied target areas. 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, figure 24, is approximately 0.2 inches in diameter, about the size of a lead pencil, and comes in 50-foot, 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. The M 700 time fuse is illustrated in figure 24.

- **Improvised Safety Fuse.** Fusing can be made from 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 a consistency of melted glue and is squeezed into macaroni-shaped tubes that are subsequently cut in short lengths. The ether and

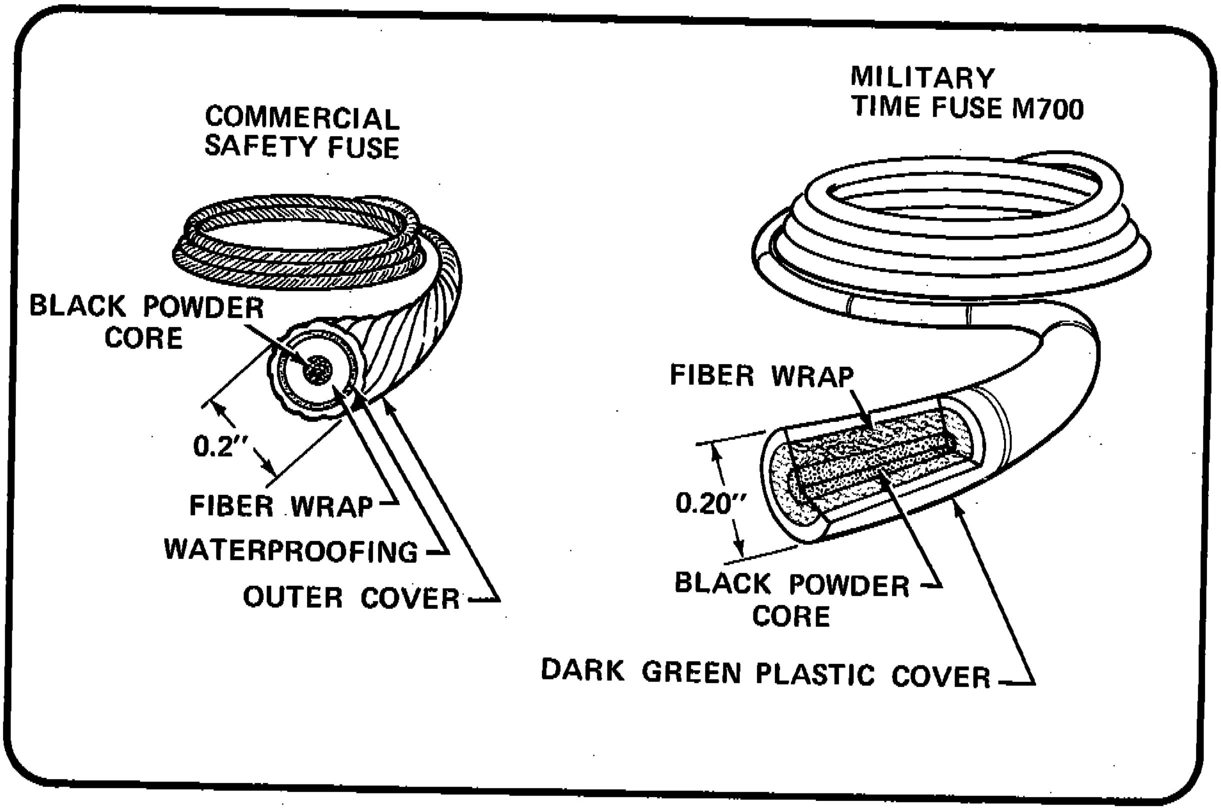

Figure 24
SAFETY FUSES

alcohol used to dissolve the guncotton are evaporated, leaving a hard substance. The small cylindrical powder grains resulting from this process are generally 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 irregular shaped granules. Smokeless powders of all types are sold in tin flasks, glass jars, plastic containers, and kegs of varying weights up to 25 pounds.

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 fuze 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. As illustrated in figure 25, 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 the most common. Number 6 blasting caps are approximately 1 1/8 inch long, with an outside diameter of ¼ inch. Number 8 blasting caps have the same diameter and are about 1¼ inch long.

Electric blasting caps with leg or lead wires 24 feet 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 4 to 300 feet, are made of 22 gauge copper wires for lengths up to 24 feet and 20 gauge copper for longer lengths. Most commercial blasting caps employ lead wires of two different colors to facilitiate making electrical connections. For use in coal mines, blasting caps of Number 6 strength are provided with iron wires with light colored insulation so that the wires can be seen more easily in low light levels. The iron is added to the wire to make it easier to magnetically separate the wire pieces from the broken coal. In salt mines, on the other hand, dark colored wire insulation is used to improve visibility against the white backgrounds of that environment.

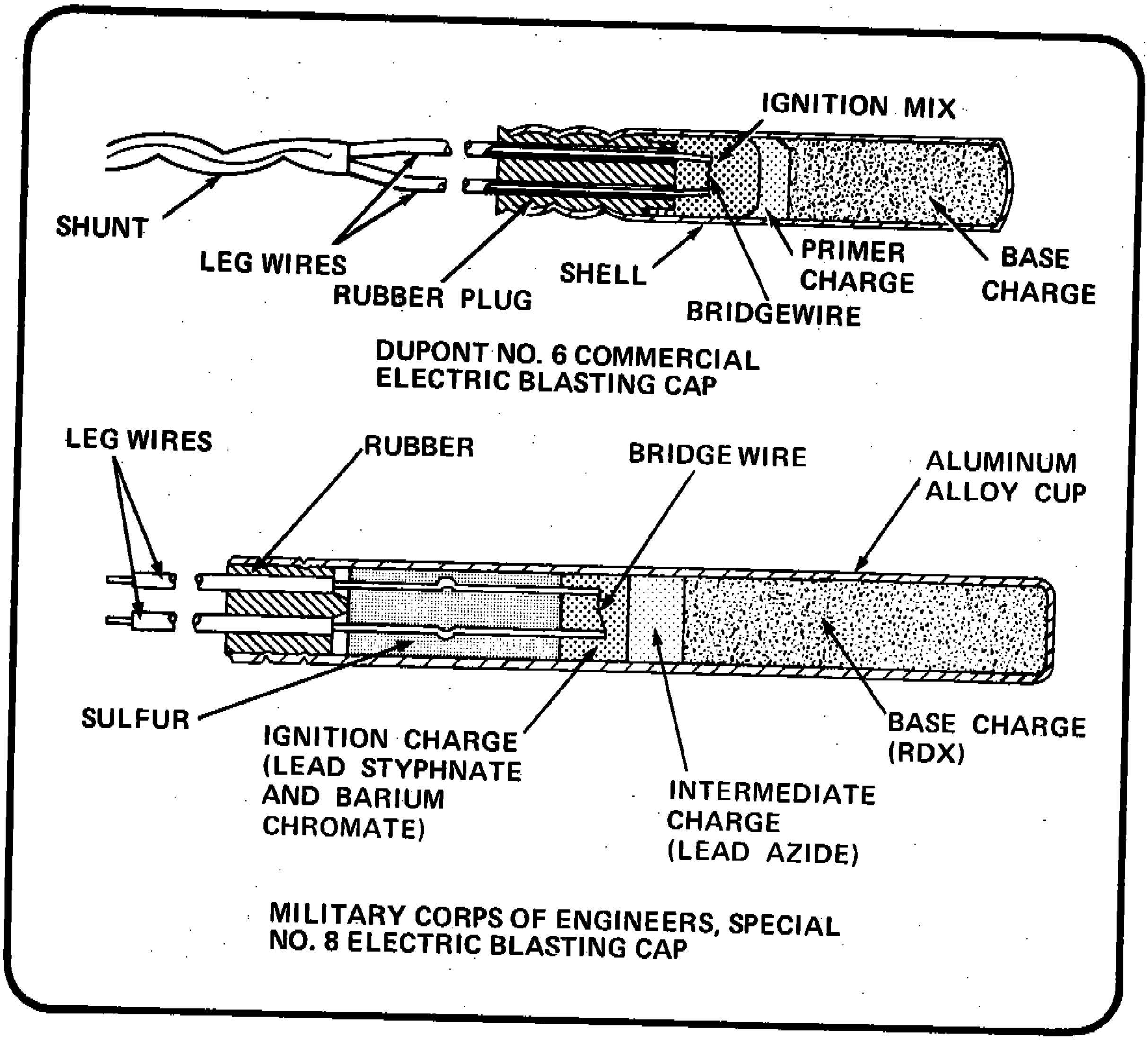

Figure 25
ELECTRIC BLASTING CAPS

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. The normal individual packing and shunting provided for electric caps are illustrated in figure 26.

Special types of electric blasting caps are manufactured for seismograph work, open hearth steel furnaces, and other tasks requiring very short delays. The delays built into these special blasting caps range from 0.5 to 1.5 milliseconds and are indicated by tags attached to each blasting cap as illustrated in figure 27.

- **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 spit of flame provided by a safety fuse or other flame

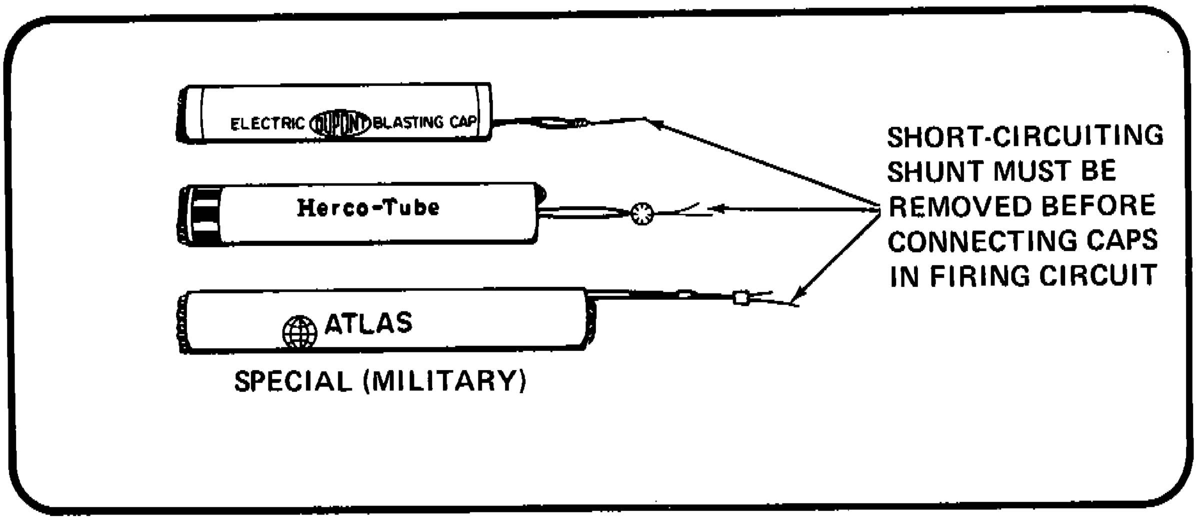

Figure 26
EXAMPLES OF PACKING AROUND ELECTRIC BLASTING CAPS

producing device. As illustrated in figure 28, 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 1 3/8 inches long and Number 8 are 1 1/2 inches long with outside diameters of approximately 0.240 inches. Some nonelectric caps may be larger. For example, the standard issue U.S. Army Corps of Engineers Special Number 8 blasting cap is 2.35 inches long and 0.241 inches 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.

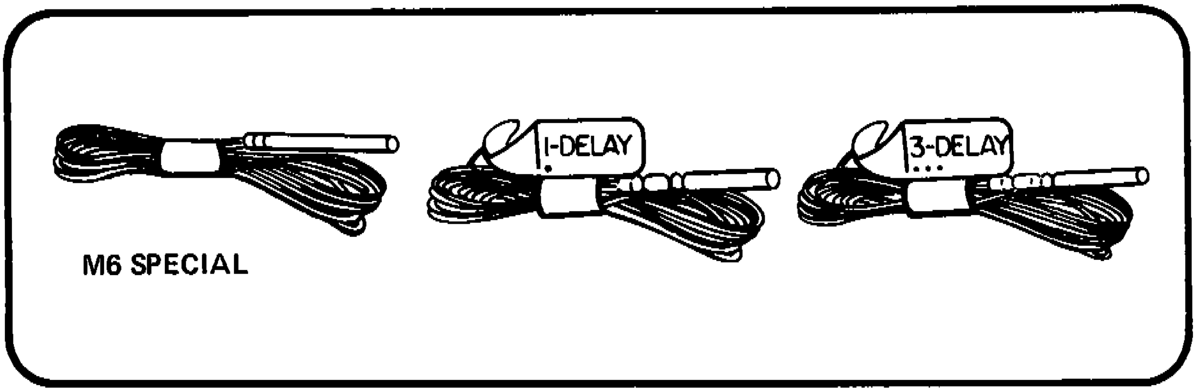

Figure 27
DELAY ELECTRIC BLASTING CAPS

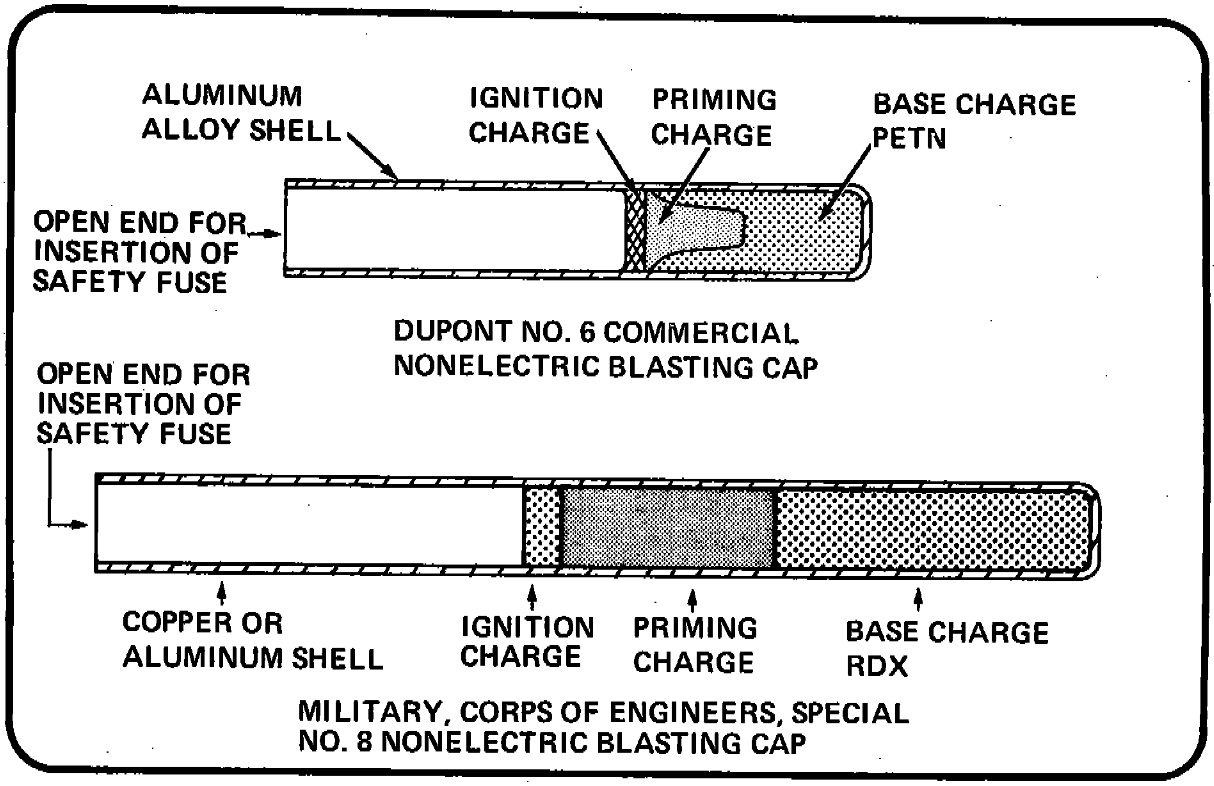

Figure 28
NONELECTRIC BLASTING CAPS

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

- **RDX (Cyclonite).** RDX, one of the most powerful explosives, is generally used as the base charge in electric and nonelectric blasting caps and is also used as a commercial booster charge. RDX is a white, crystalline, odorless, powder much like fine granular sugar. Its crystals are sensitive to heat, shock, and friction and if RDX crystals are found, they should be wetted down and transported in a wet condition.

- **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. When in contact with copper and in the presence of moisture, lead azide reacts to produce an extremely sensitive and dangerous compound called copper azide. Because of this reaction with copper, explosive manufacturers do not normally load lead azide into copper shell blasting caps. Lead azide is extremely sensitive to heat, shock, friction, and static electricity. The form of lead azide normally used in blasting caps and fuze 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.

- **Mercury Fulminate.** Mercury Fulminate was used extensively in the past as the base charge in the manufacture of commercial blasting caps. It is an excellent initiator. The public safety officer will normally encounter mercury fulminate as the base charge in older type commercial caps. The newer caps use RDX or PETN. Mercury fulminate is white, grey, or light grey with a yellowish tint and will be found in a sparkling crystal form. Under magnification, the crystals will have a octahedral form usually truncated. Mercury fulminate is extremely sensitive to heat, shock, friction, and static electricity.

Detonating Cord. Detonating cord is a round flexible cord containing a center core of primary high explosive. As illustrated in figure 29, the explosive core of the detonating cord is protected by a sheath of various textiles, waterproofing materials, or plastics.

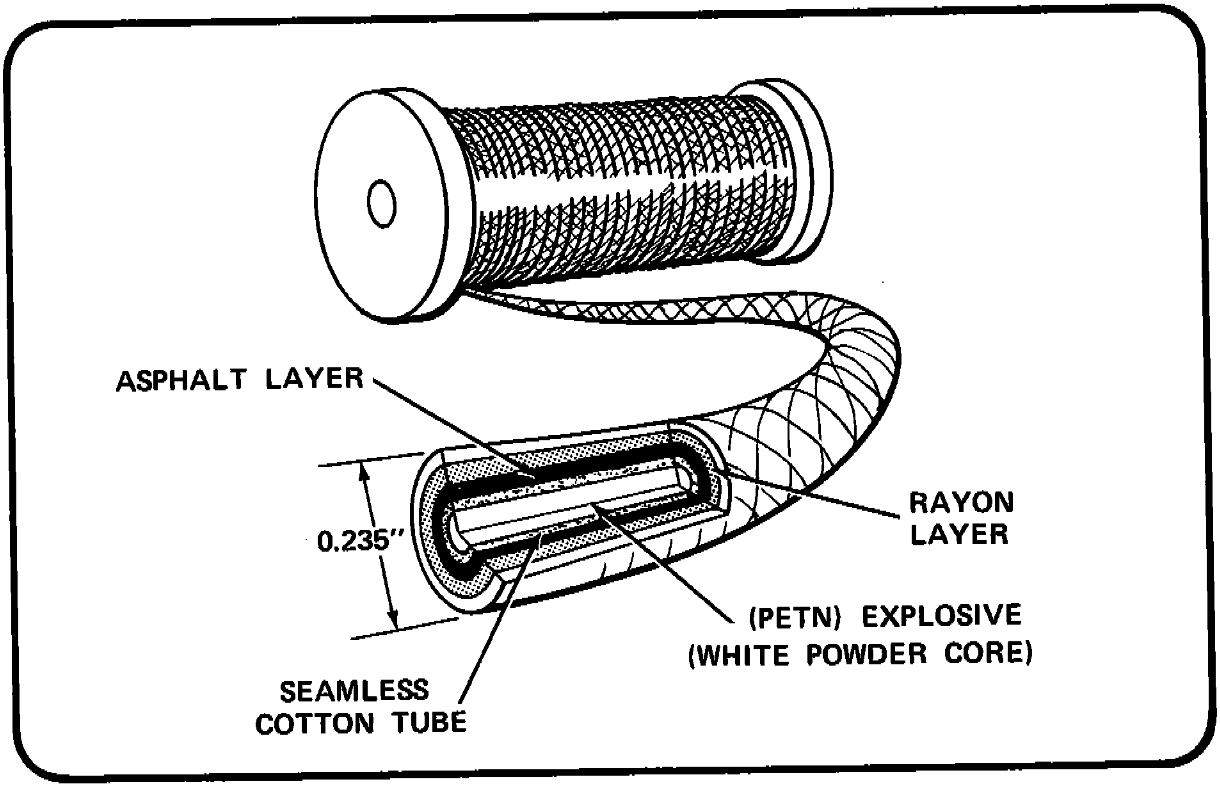

Figure 29
DETONATING CORD

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. Typical markings are illustrated in figure 30.

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. The white crystalline powder core is PETN (Pentaerythrite 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 a light grey. PETN has no identifiable odor.

Detonating cord is frequently known by a brand name such as *Primacord, Primex, Detacord, Detonating Fuse,* or *Cordeau Dėtonant* Most of the common detonating cords are of the high energy military type, which contains about 60 grains of PETN per foot. Detonating cords up to 400 grains 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 grains of PETN per foot. Other low energy cords include *Mild Detonating Fuse* and *E-Cord*, both with reduced core loading per foot.

Another special type of detonating cord is employed in oil well jet perforating. This detonating cord has a black plastic outer sheath and the explosive core is 70 or 80 grains per foot of RDX. RDX is used because it is suitable for exposure to crude oil and well fluids at high pressure and temperatures up to 325°F for 2 hours without deterioration or detonation.

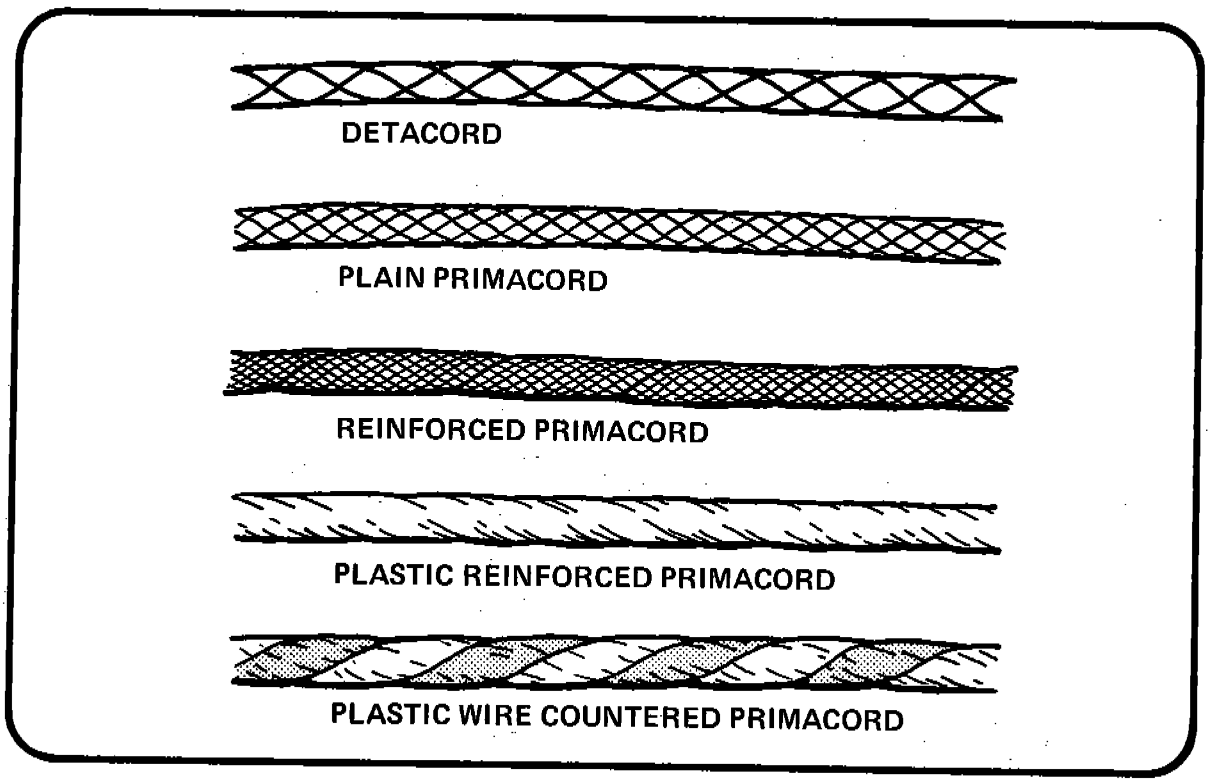

Figure 30
DUPONT DĖTONATING CORD MARKINGS

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. Several methods of priming explosive charges with detonating cord are illustrated in figure 31.

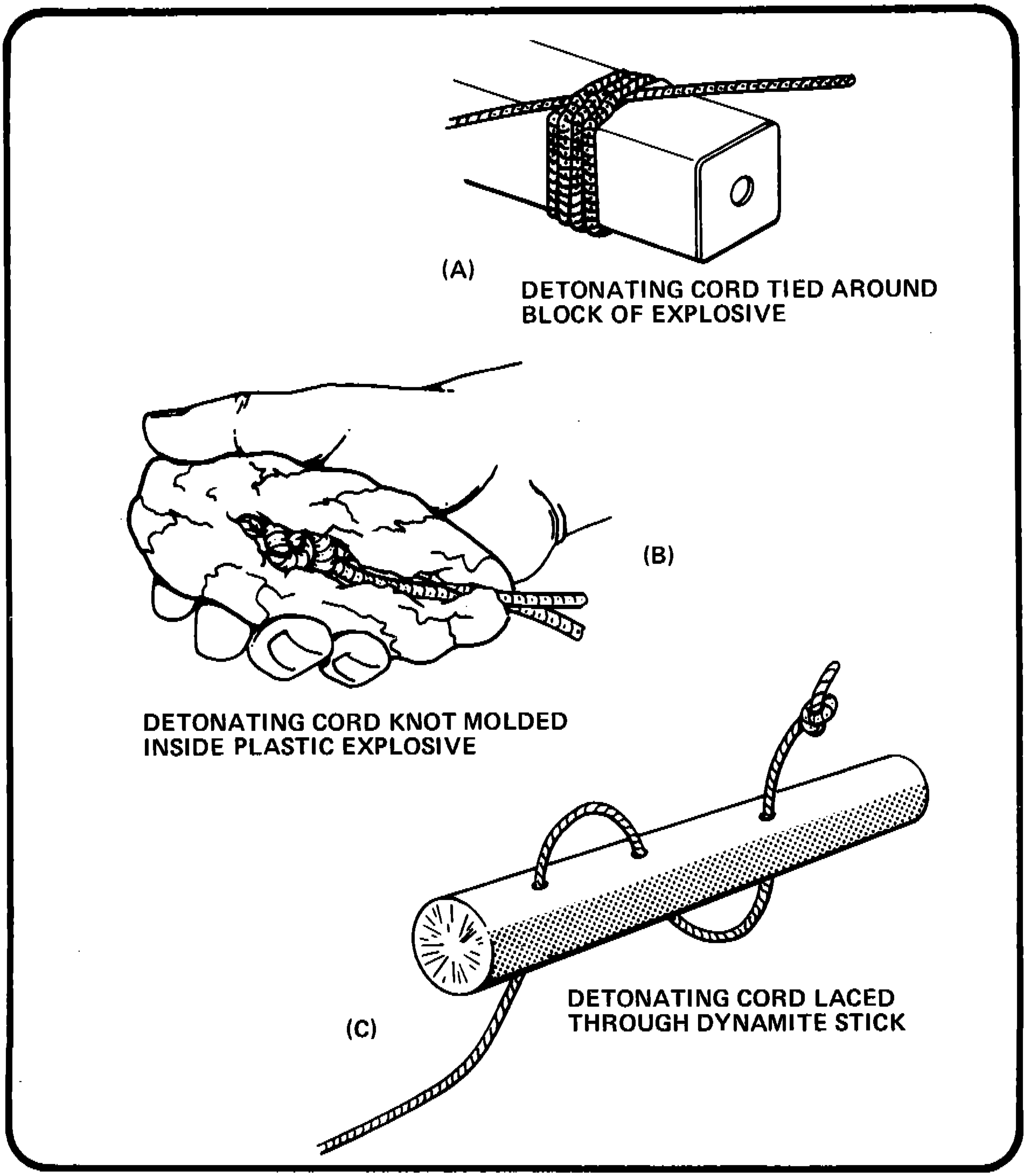

Figure 31
EXAMPLE OF USING DETONATING CORD TO PRIME EXPLOSIVE CHARGES

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 200 feet apart in a straight line would require a minimum of about 2,000 feet 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 as illustrated in figure 32.

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 21,000 feet or nearly 4 miles per second.

Secondary High Explosive Boosters

Secondary high explosive boosters are explosives which 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 carefully handled. Most, for example, will detonate on sharp impact such as that resulting from a

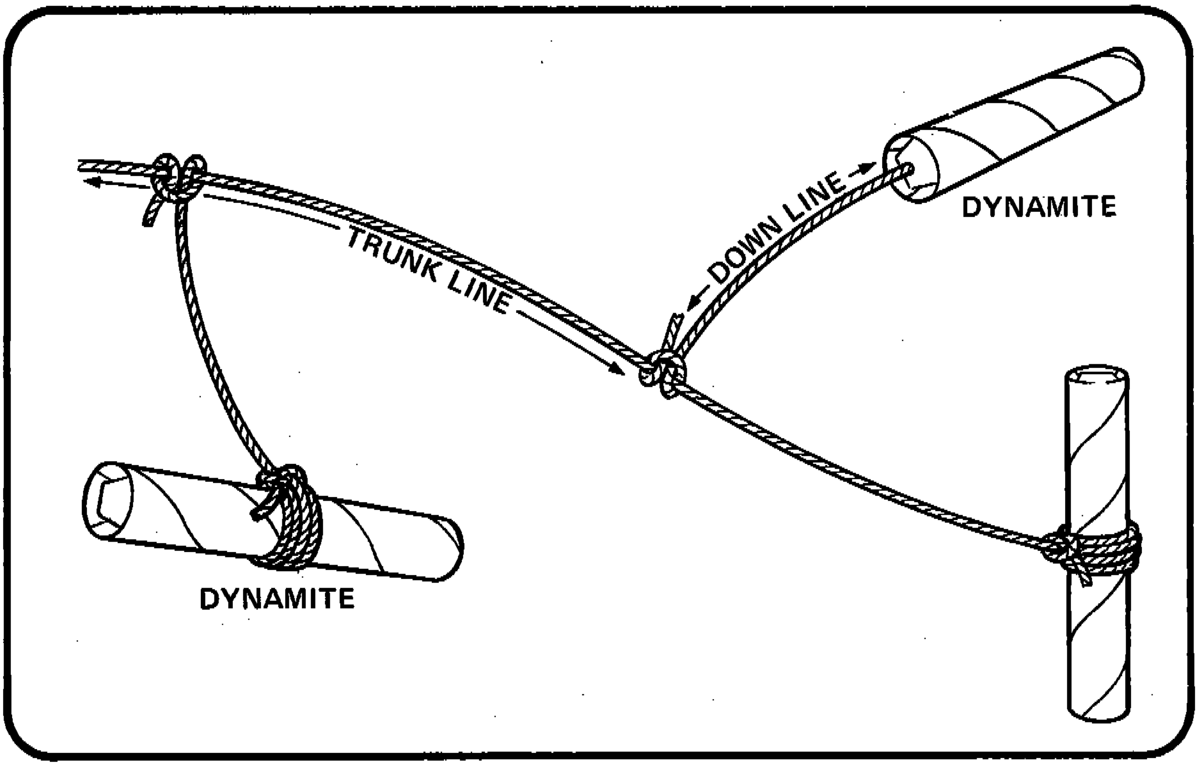

Figure 32
USE OF DETONATING CORD FOR SIMULTANEOUS NONELECTRIC DETONATION OF EXPLOSIVE CHARGES

small arms bullet. Due to this sensitivity, boosters are normally used in small amounts ranging from several ounces up to a pound in weight.

Boosters are usually cylindrical in shape, as illustrated in figure 33, 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. Some boosters are supplied in tin cans with threaded, interlocking ends that allow the booster units to be assembled into a long, tightly joined unit. 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 insure complete detonation of the main charge explosives.

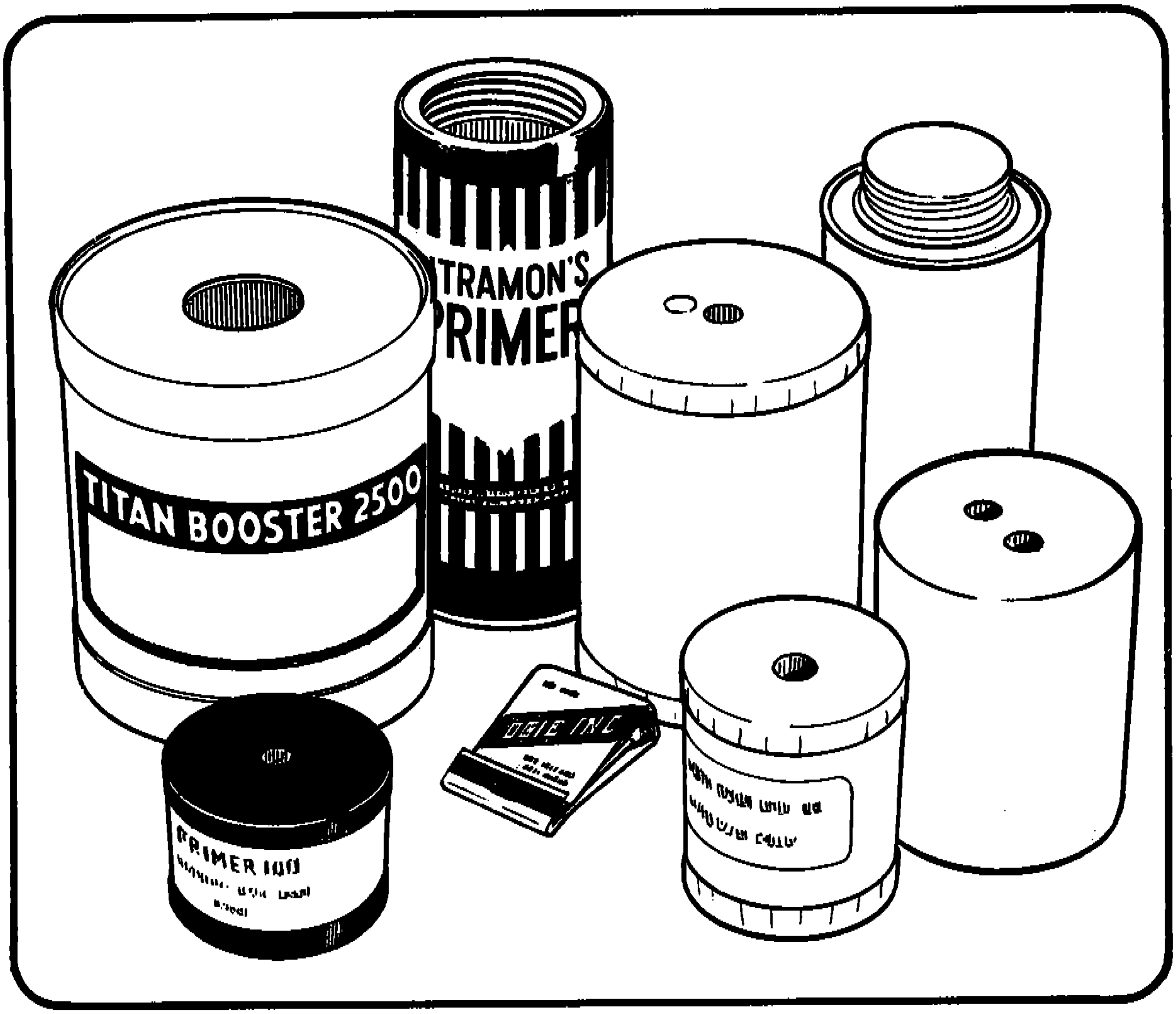

Figure 33
BOOSTERS WITH MATCHBOOK FOR SIZE COMPARISON

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 grey to yellow and has a detonation velocity of 24,500 f.p.s.

- **RDX.** Alone and mixed with other explosives, RDX is used in several commercial primers and boosters. The Titan Booster 25, illustrated in figure 34, is designed primarily for underwater work. It consists mainly of RDX in a 4 1/2 by 5/8-inch 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. When used as a booster, tetryl is usually found in pellet form.

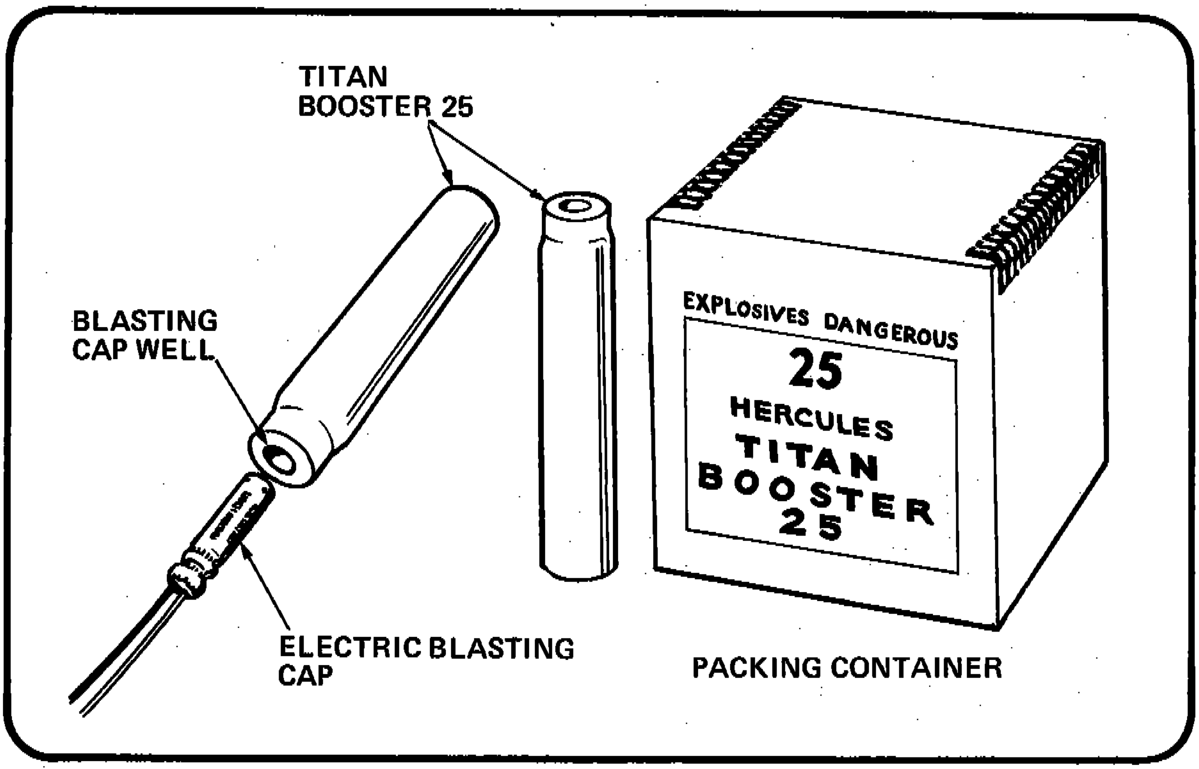

Figure 34
HERCULES TITAN BOOSTER 25

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 and has consequently been one of the explosives most frequently used by criminal bombers.

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 liquid nitroglycerin, oxidizers, and a binder 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 as manufactured. 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. When the nitroglycerin content is tripled, the quantity of other energy producing ingredients is proportionally reduced, offsetting some of the power increase achieved through the greater nitroglycerin content. Thus, the 60 percent dynamite is actually only about 1½ times as strong as 20 percent dynamite.

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 1 1/8 to 1 1/2 inches in diameter and are about 8 inches long. In less common larger sizes, dynamite cartridges may be 4 to 6 inches in diameter and up to 38 inches in length as illustrated in figure 35.

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.

The Department of Transportation (I.C.C.) regulations limit the largest size cartridge that may be shipped to 65 pounds in weight, 12 inches in diameter, and a maximum length of 36 inches. However, dynamites of less than 10 percent nitroglycerin content are unlimited with regard to length.

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

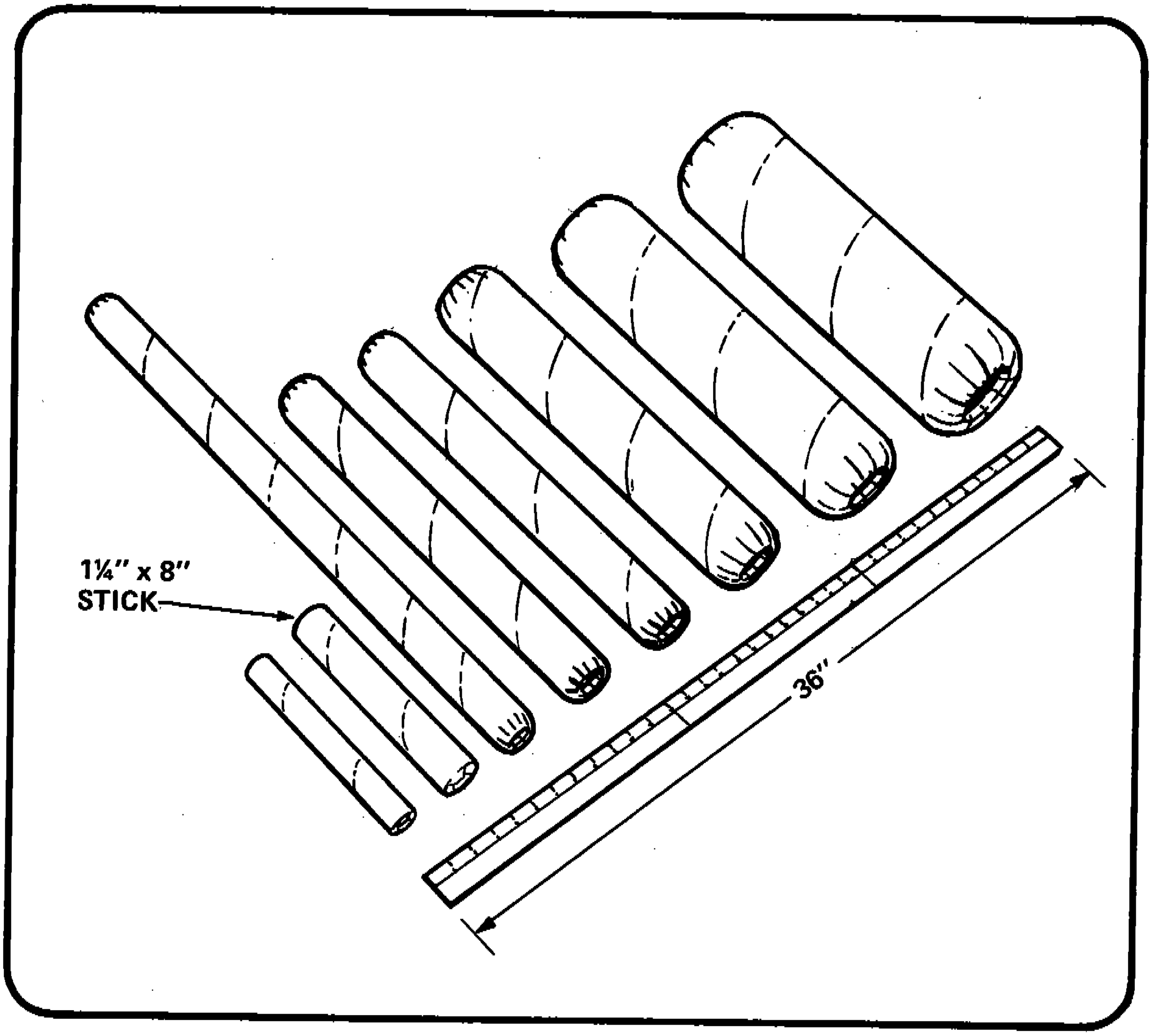

Figure 35
STANDARD DYNAMITE CARTRIDGE SIZES

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 very persistent and severe headache. Nitroglycerin liquid and vapors are quickly absorbed by the body and enter the bloodstream rapidly, producing the headache. Although aspirin has little effect on such headaches, some relief may be obtained from strong black coffee or caffeine citrate.

When removed from its wrapper, straight dynamite will generally be 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 through 60 percent, with the more common rating being 30, 40, 50 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 oil substance. In such cases, the material should be moved only by civilian or military 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 1¼ by 8 inches for use in ditch blasting. It is favored for this purpose because, if soil conditions are suitable, it is sufficiently sensitive to detonate by propagation. This eliminates the need for individual blasting cap or detonating cord priming of each stick. The principal characteristic of ditching dynamite is its high detonation velocity of over 17,000 f.p.s., which imparts a powerful shock wave and produces a good earth shattering effect.

- **Ammonia Dynamites.** In the manufacture of ammonia dynamites, a portion of the nitroglycerin content is replaced by ammonium nitrate. This produces a dynamite which is lower in cost and less sensitive to shock and friction than straight dynamite. Since it has 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 to 60 percent with detonation velocities in the range of 7,000 to 9,000 f.p.s., although special purpose formulas producing velocities from 6,500 to 12,200 f.p.s. may 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 to 90 percent. It is an inherent property of gelatin dynamite to detonate at two velocities. Unconfined, it will usually detonate at about 7,000 f.p.s., but when confined, gelatin dynamites will detonate in the range of 13,000 to 22,000 f.p.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 to 90 percent with detonating velocities ranging from about 13,000 to 17,000 f.p.s.

- **Military Dynamites.** Military dynamite is not a true dynamite in that it is manufactured of 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 as illustrated in figure 36. This marking identifies a cartridge size difference only, since all military dynamite detonates at about 20,000 f.p.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 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.

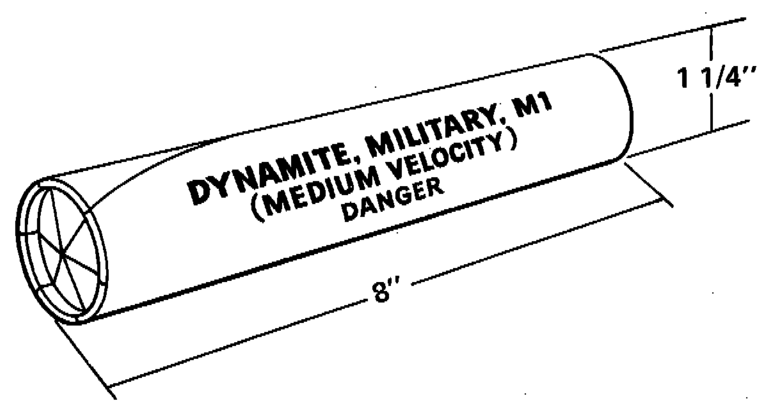

Figure 36
MILITARY DYNAMITE

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 to the touch. It does not have a noticeable characteristic odor, nor does it cause the headaches typical of the true dynamites.

All dynamites may be detonated using either electric or nonelectric caps or detonating cord. Figures 37 through 39 illustrate standard methods of preparing dynamite sticks for detonation. Since blasting caps are extremely sensitive, it is always advisable to force a cavity in the dynamite stick before attempting to insert the cap. The ordinary blasting cap crimper tool is provided with a pointed handle for the purpose of making a cavity in the explosive for the insertion of the blasting cap.

Permissibles or Permitted Explosives. A permissible explosive is one which has been approved by the U.S. Bureau of Mines or the British Ministry of Fuel and Power for use in gas or dust-filled mines. When detonated or exploded, all explosives produce a flame that varies in volume, duration, and temperature. Black powder produces the longest lasting flame, while dynamites typically produce a shorter lasting, but more intense flame. Permissible explosives are especially designed to produce a flame of low volume, short duration, and low temperature. This is accomplished by adding certain salts to the explosive formula in order to cool or quench the flame to prevent the ignition of gas or dust within the confined space of a mine.

Permissible explosives are generally modified types of gelatin or ammonia dynamites. They are similar in packaging and appearance to other dynamites.

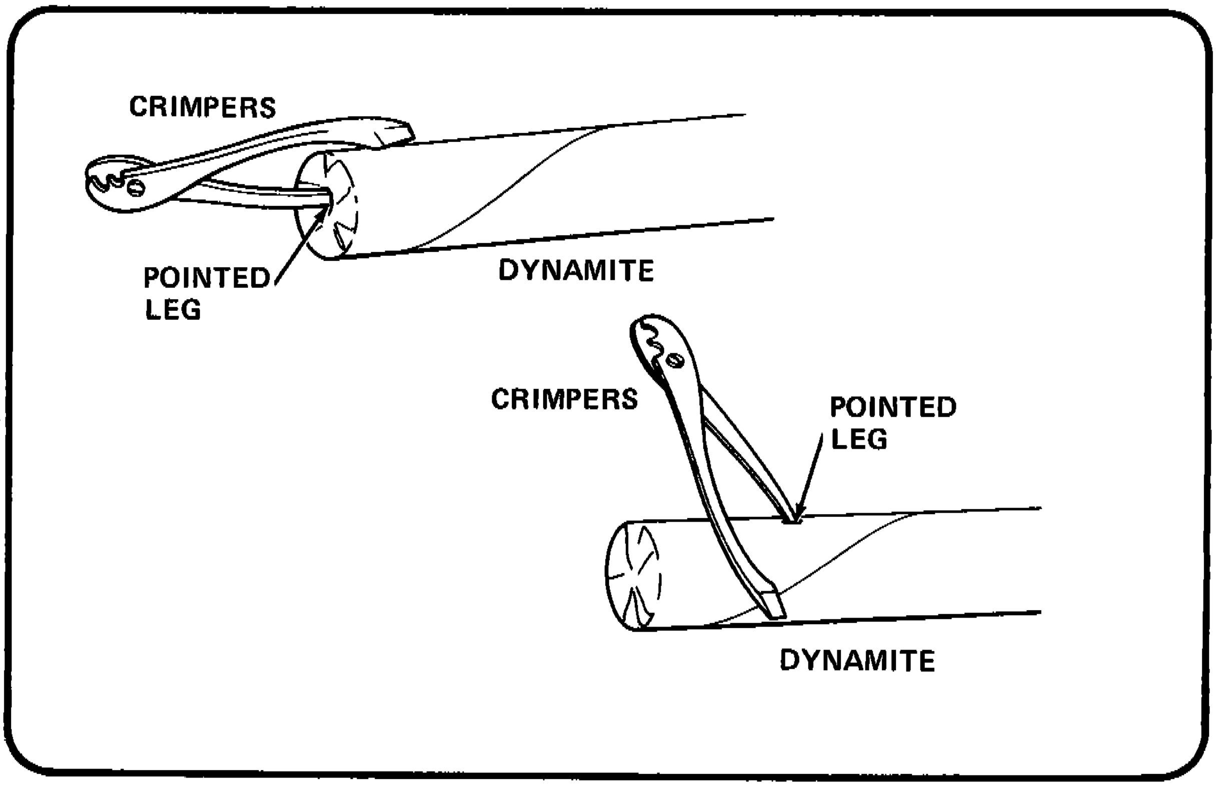

Figure 37
PREPARING DYNAMITE STICKS FOR INSERTION OF THE BLASTING CAP

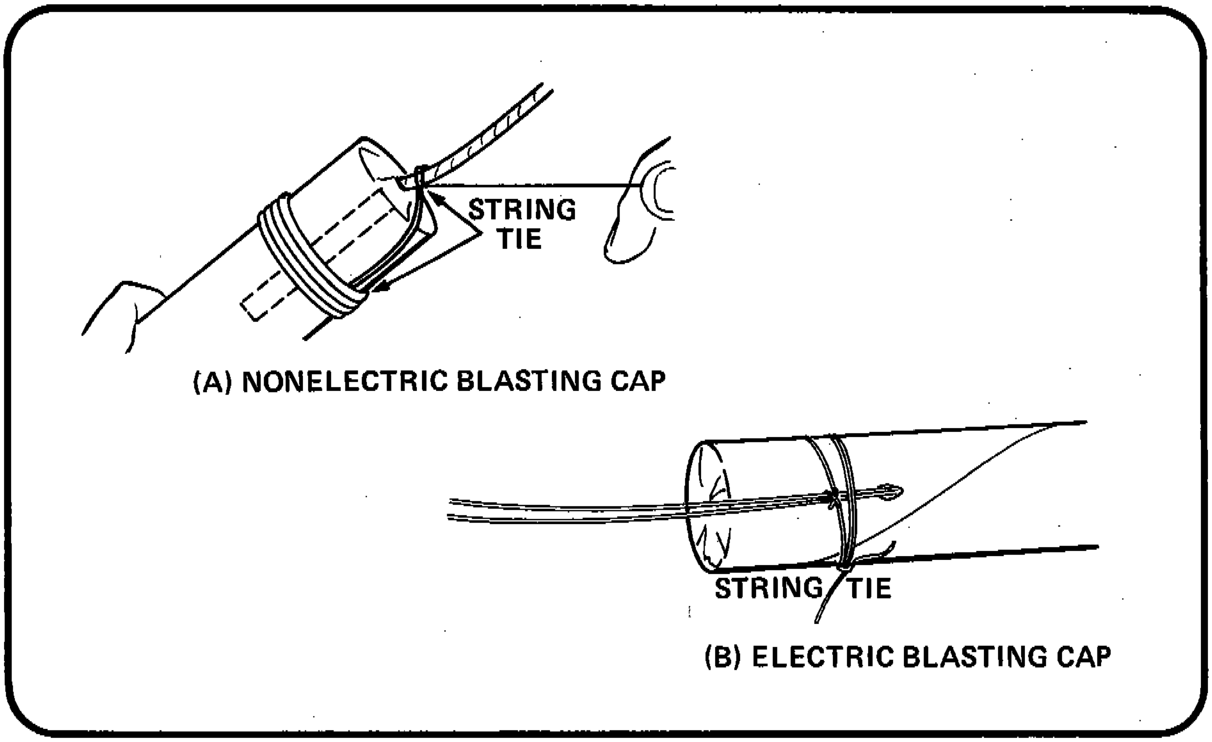

Figure 38
DYNAMITE END-PRIMED (A) AND SIDE-PRIMED (B)

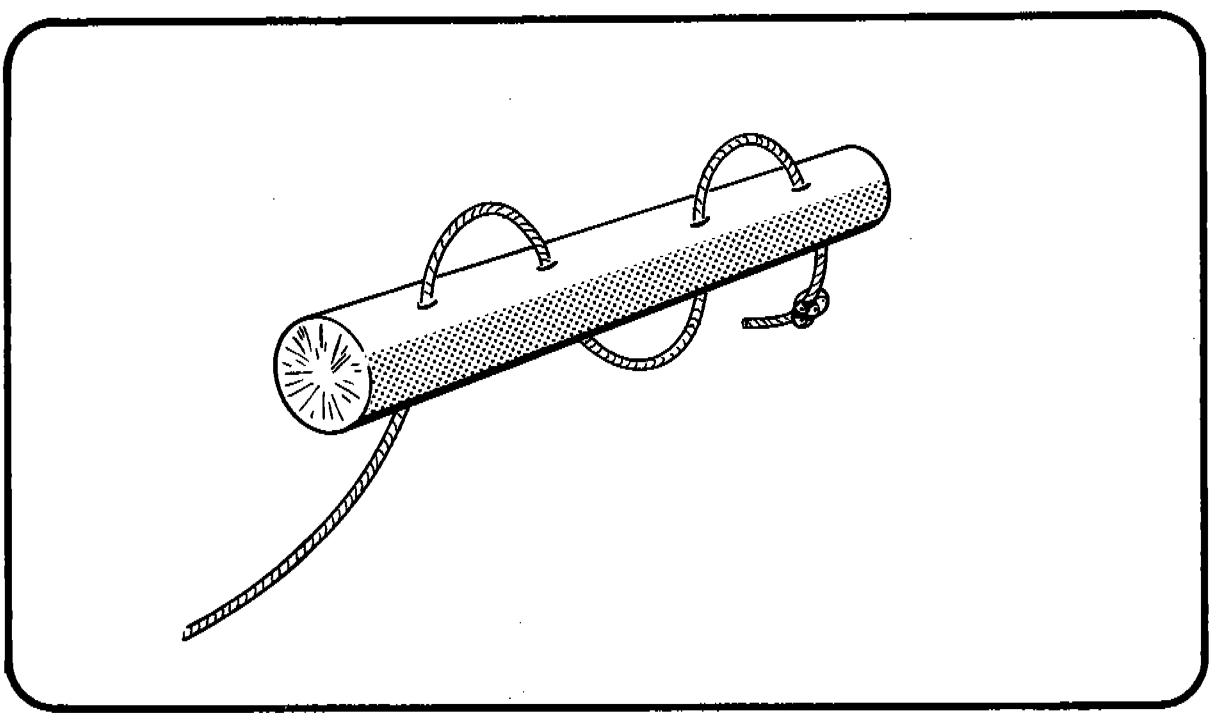

Figure 39
DYNAMITE STICK PRIMED WITH DETONATING CORD

Ammonium Nitrate. Ammonium nitrate explosive 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 saline or 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 11,000 f.p.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, including bombers. 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. This mixture is referred to as "prills and oil" or ANFO (ammonium nitrate fuel oil), and its use is fairly widespread because of its low cost.

Ammonium nitrate should be handled with some degree of caution, because it is a strong oxydizing 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 non-sparking 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 or *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 4 to 11 inches in diameter, 16 to 24 inches in length, and weigh from 13.5 to 85 pounds. NCN is similar to 50 or 60 percent blasting gelatin in strength, but is much less sensitive to handle. NCN cannot normally be detonated with a blasting cap or detonating cord alone, but requires a high explosive booster.

Another group of blasting agents is made up of NCN with high explosive mixtures added, usually TNT. The addition of the high explosive increases strength and density and, of course, results in the mixture being classed as a high explosive. Used for more difficult blasting problems, reinforced NCN has been found to be equal to 80 or 90 percent gelatin. It is packaged in the same way as NCN.

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 a 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. Free running agents are packaged in 12½, 50, 80, and 100-pound multiwall paper bags. asphalt-laminated burlap bags, or polyethylene bags. 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 nitro-carbo-nitrate (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. They are packaged in polyethylene bags 2 to 8 inches in diameter or may be delivered to the blasting site by special pump trucks.

Two Part Explosive – Kinepak. Kinepak explosives are two-part explosives which are inert until mixed. When mixed and detonated with a Number 6 cap, Kinepak 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 Kinepak explosives were developed as a direct replacement for dynamites and commercial PETN-RDX boosters.

Kinepak component A (figure 40) is a pink liquid which is poured into component B, a fine white powder, to form the explosive material. Mixture of the two components takes place inside a plastic coated aluminum foil pouch and takes about 10 seconds without visible chemical reaction. Separately, neither component A nor component B is classified as an explosive or even as a hazardous chemical. Unmixed Kinepak explosive may be shipped by common carrier or by airfreight with no special handling required.

As a result of its unique characteristics, Kinepak explosive may be carried in public safety vehicles without violating ICC regulations and, at the same time, presents no hazard to the public, because it is not an explosive until it is mixed. Further information on Kinepak may be obtained from Kinetics International Corporation, 2712 Rollingdale Lane, Dallas, Texas 75234.

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, and the larger bottle contains a liquid-filled can in the bottom. To form the explosive, the contents of the small bottle is 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. Figure 41 illustrates the Astrolite containers and the mixing process for preparation of the explosive.

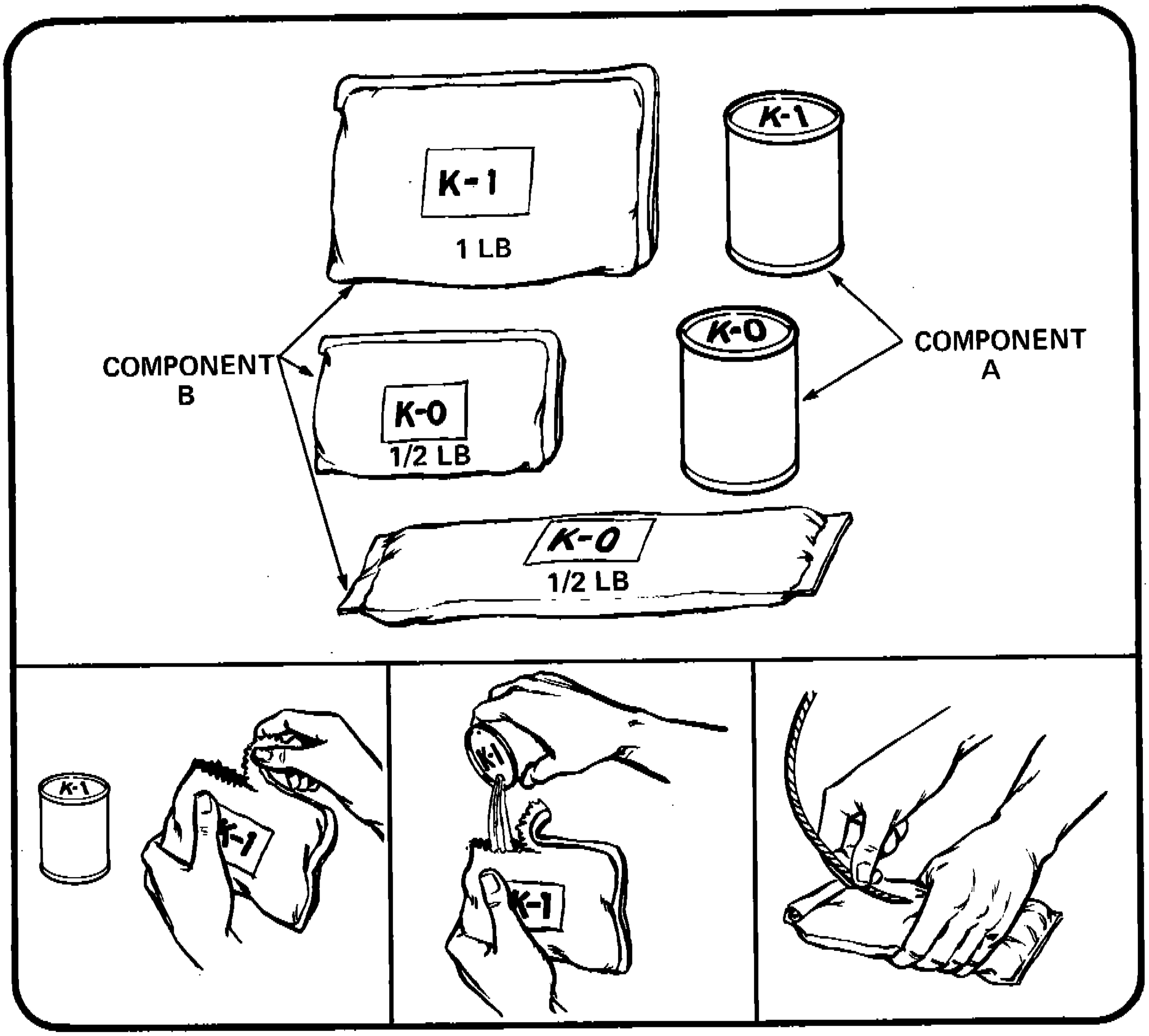

Figure 40
KINEPAK TWO PART EXPLOSIVE

Astrolite is clear in color and smells strongly of ammonia. Excessive inhalation of vapors or contact with the skin should be avoided. Astrolite reacts with copper, brass, and most other metals, making the use of aluminum shell blasting caps necessary. Astrolite also reacts with tetryl and will cause it to detonate. Additional information on Astrolite may be obtained from the Explosives Corporation of America, Excca Building, Issaquah, Washington 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 usuable underwater, and must be of a convenient size, shape, and weight for troop use.

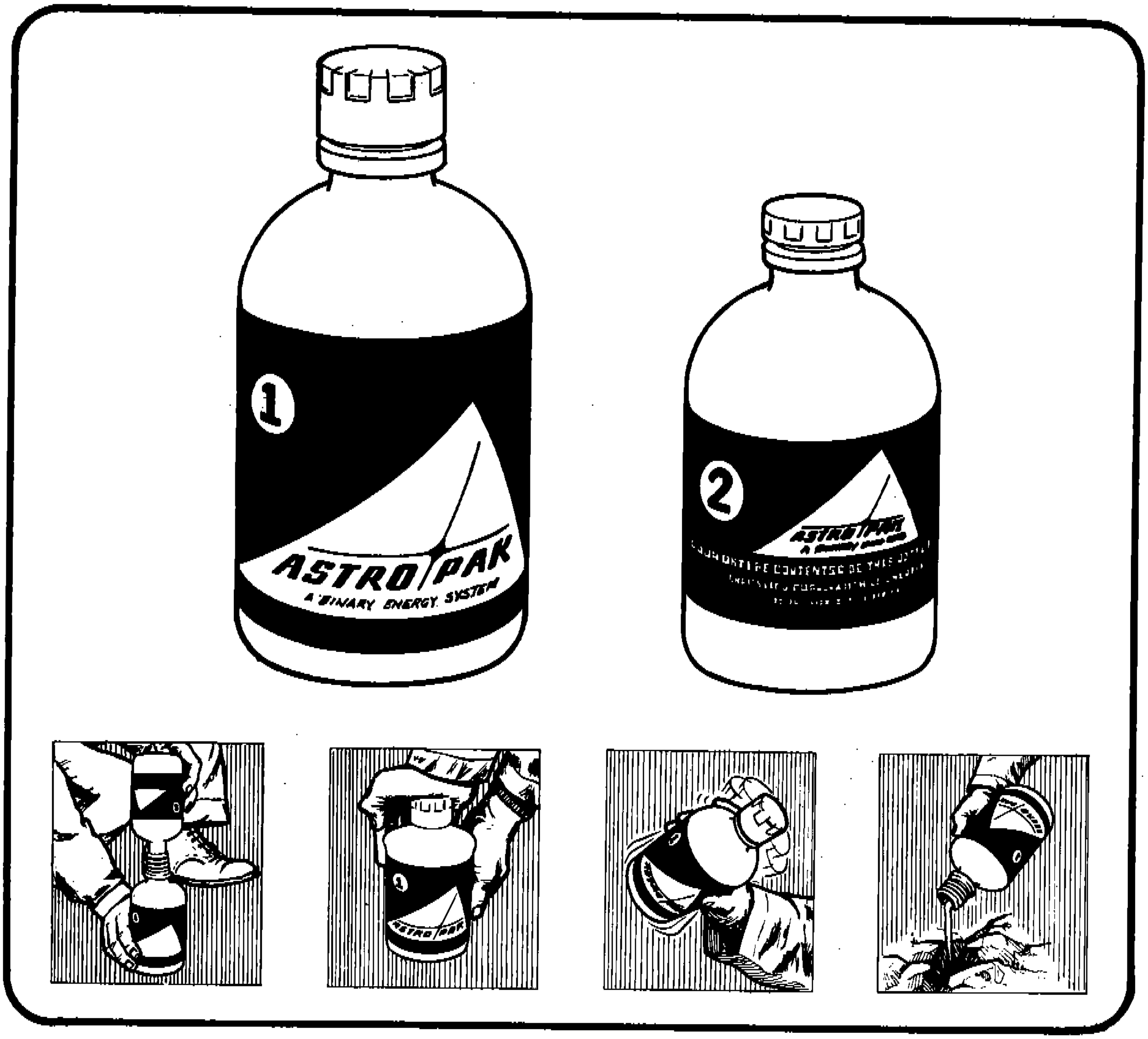

Figure 41
ASTROPAK

- **TNT (Trinitrotolune).** 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 ¼, ½, and 1-pound blocks illustrated in figure 42. These blocks are normally packed in 50-pound 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 grey smoke.

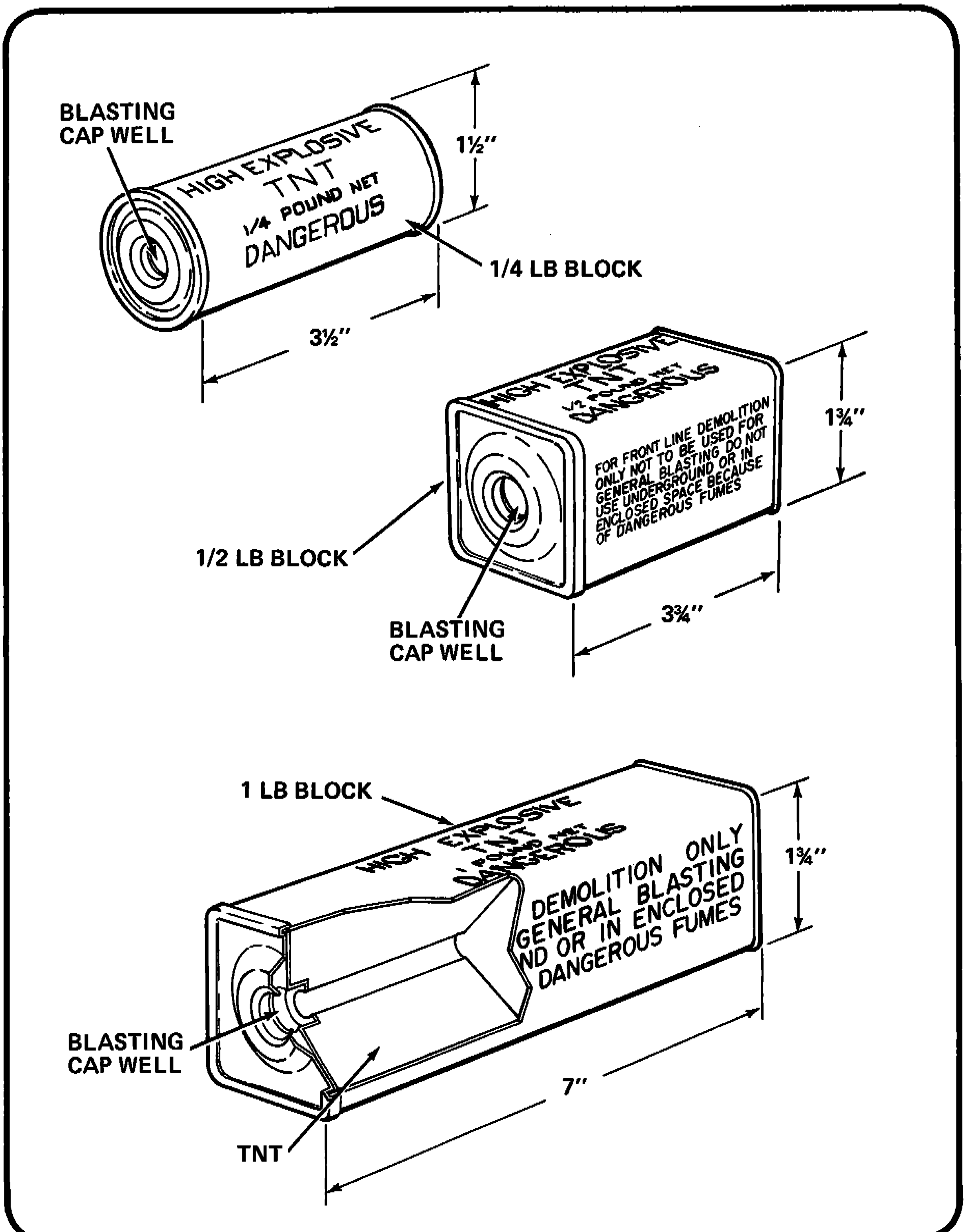

Figure 42
MILITARY TNT BLOCKS

- **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 to about 24,000 f.p.s.

  Tetrytol is manufactured for the military both as part of the M1 chain demolition package and as the M2 demolition block. The M1 chain demolition block weighs 2½ pounds, and eight blocks are spaced eight inches apart on a 192-inch length of detonating cord. This arrangement, as illustrated in figure 43, leaves 24 inches of detonating cord at both ends of the chain for the attachment of a military electric or nonelectric special Number 8 blasting cap.

  The M1 chain demolition block unit can be used in full or part along a straight line, wrapped around a target, or used in the haversack in which it is packed. The haversack contains 8 blocks, a complete chain unit, and measures 11 by 8 by 4 inches and weighs 20.2 pounds.

  The tetrytol M2 block does not have a detonating cord cast through it. Instead, each block has a tetryl booster pellet cast internally at both ends. Each block weighs about 2½ pounds, is wrapped in an asphalt impregnated paper, and has a threaded blasting cap well at each end. The M2 blocks measure 11 by 2 by 2 inches and are packed eight blocks to a haversack. 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 solid 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 illustrated in figure 44. C-3 is packaged in two different wrappers. The M3 block has a cardboard wrapper and measures 11 by 2 by 2 inches. The M5 block is wrapped in clear plastic with a threaded blasting cap well and measures 12 by 2 by 2 inches. The M3 and M5 blocks both weigh about 2½ pounds. The M3 is packed 8 blocks in a haversack, and the M5 is packed 24 blocks in a wooden box.

- **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 24,000 f.p.s. The C-4 M5A1 demolition block is wrapped in a clear plastic wrapper and measures 11¾ by 2 by 2 inches. C-4 is also supplied in a M112 demolition charge with an adhesive back. The M5A1 and M112 are illustrated in figure 45.

- **Sheet PETN (Flex-X).** Sheet PETN, called *Flex-X* by the military and *Detasheet* commercially, is a highly flexible demolition charge consisting of 63 percent PETN with pyrocellulose 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.

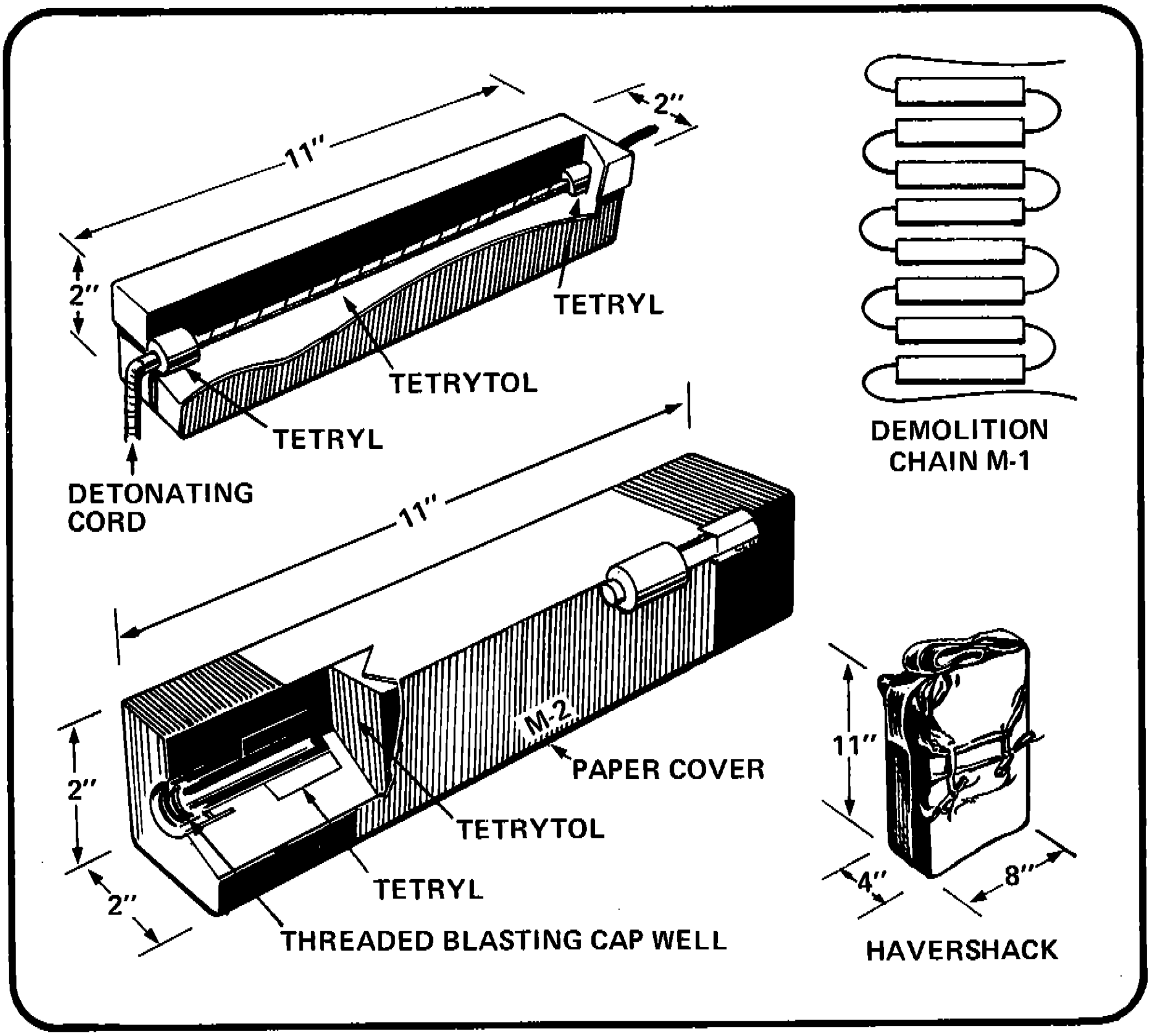

Figure 43
TETRYTOL BLOCKS

Commercially, sheet PETN is used for explosive forming, cutting, and metal hardening. The military sheet, shown in figure 46, 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 any suspicion.

Starch, flour, sugar, or cellulose materials can be treated to become effective explosives. Powder from shotgun shells or small arm ammunition, match heads, firecracker powder, and ammonia

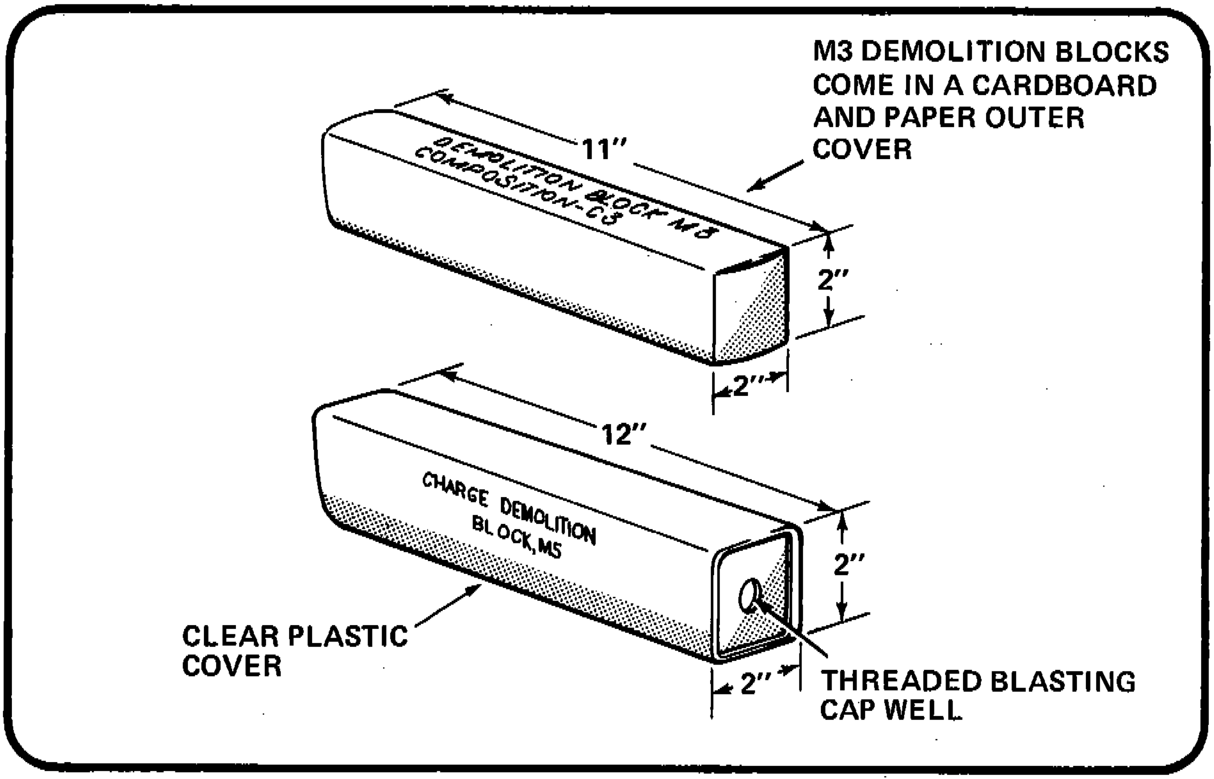

Figure 44
COMPOSITION C-3 DEMOLITION BLOCKS

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 functioned 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.

As noted above, improvised main charge explosives are limited only by the materials available and the training and imagination of the bomber. Some main charges are produced by using existing

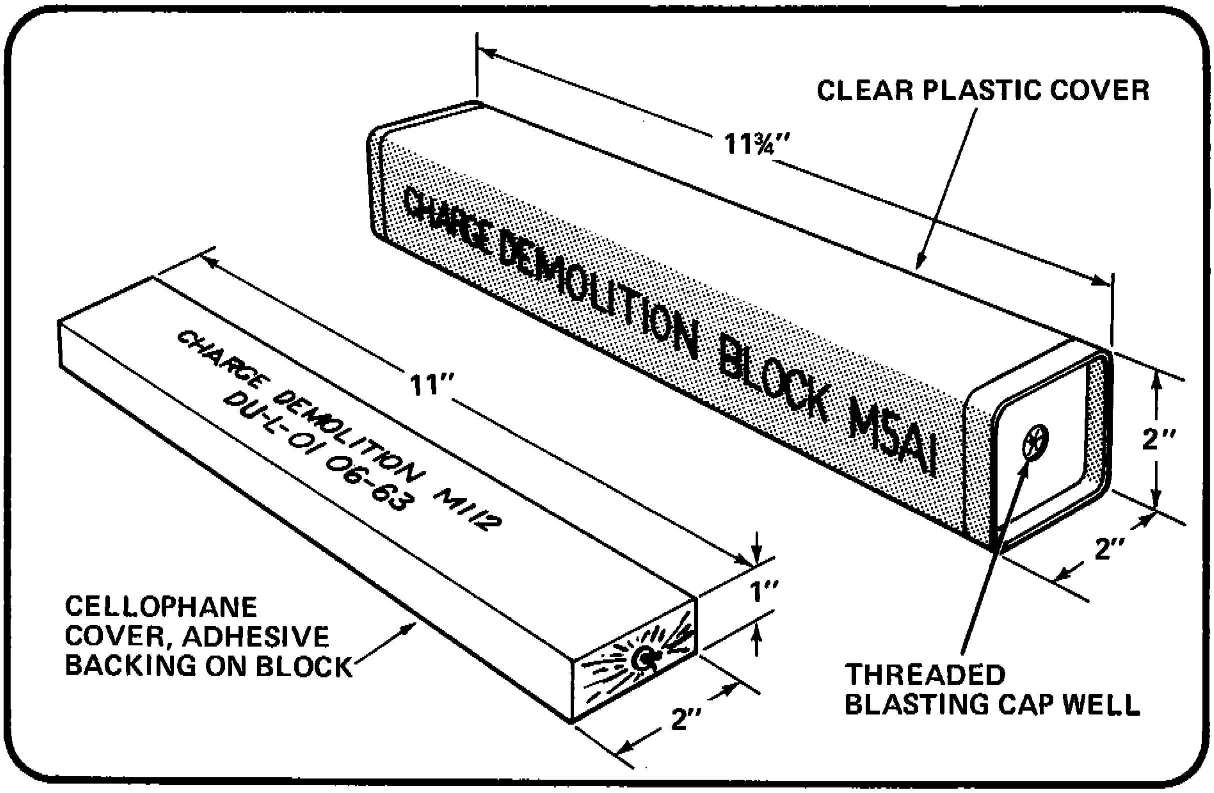

Figure 45
COMPOSITION C-4 DEMOLITION BLOCKS

commercial compounds converted to the bomber's tactical use, and in other cases the main charge explosive is chemically formulated and manufactured from materials available from grocery or drug stores.

The most widely improvised main charge explosives are black and smokeless powder. Black powder is especially easy to manufacture and, when dry, is also one of the most dangerous explosives to handle because of its sensitivity to sparks, flame, or friction. Other common improvised explosives include:

- **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 should always 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.

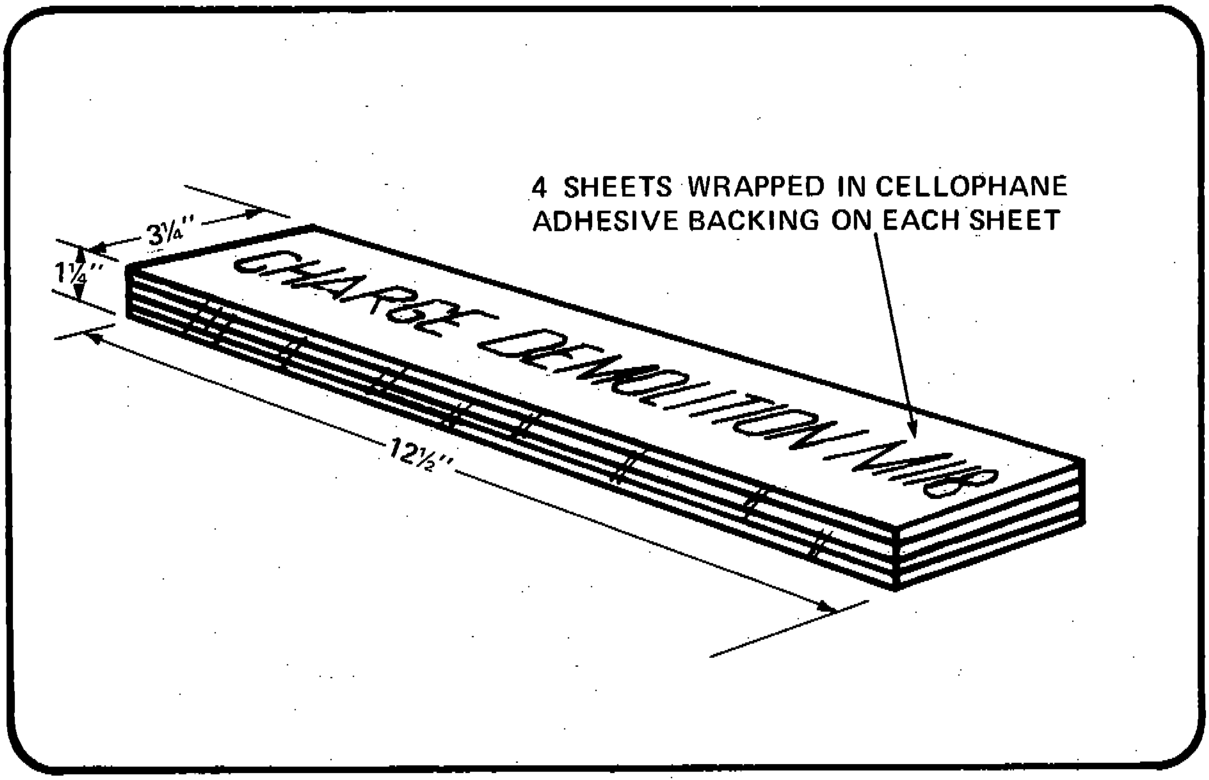

Figure 46
M118 MILITARY SHEET PETN DEMOLITION CHARGE

- **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.

- **Other Explosive Compounds.** The list of explosives that can be manufactured from readily available chemicals and existing materials is virtually endless, a few of the more common explosives are listed in figure 47.

Nitroglycerin. Although nitroglycerin is not often employed as a main charge either in its manufactured or improvised state, it does present special public safety problems which would seem to justify its inclusion in this publication.

Nitroglycerin is the main explosive component of straight dynamite and is found in lesser concentrations in a number of other explosives. Medical use of nitroglycerin is prescribed for coronary ailments, the normal dosage being 0.0005 grams per capsule. Pure nitroglycerin is employed in small quantities by petroleum companies to fracture subterranean formations encountered in oil or gas well drilling and may also be used to "snuf out" oil well fires. Criminals have used liquid nitroglycerin to blow open safes and vaults, and liquid nitroglycerin may also be encountered as exudation or leakage from badly deteriorated dynamite.

Ammonium Nitrate and Aluminum Powder (Ammonium Nitrate Dry Explosive)

Nitric Acid and Cellulose Materials (Sprengel Explosive)

Nitric Acid and Urine

Chlorate or Potash, Chromate of Potash, Sugar, Wax (Berge's Blasting Powder)

Potassium Chlorate, Charcoal, Sulfur (Chlorate Black Powder)

Ammonium Nitrate, Stearic Acid, Aluminum Powder (French Ammonal)

Potassium Nitrate, Charcoal, Sulfur (Black Powder)

Potassium Chlorate, Limed Rosin (Pyrodialyte)

Potassium Chlorate, Limed Rosin, Flake Aluminum (Steelite)

Figure 47
IMPROVISED EXPLOSIVE MIXTURES

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, and it has a sweet taste.

In a pure state, nitroglycerin is very sensitive to heat, shock, and friction. Sensitivity is increased markedly by the application of heat. When frozen, nitroglycerin is less sensitive than when it is in a liquid state, however in a semi-frozen 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 jar, overheating, or chemical reaction with container materials and impurities. In certain cases it has been known to detonate for no apparent reason at all. In the event that public safety officers should encounter what is believed to be nitroglycerin, utmost caution should be exercised. To assist in determining if an encountered liquid is, in fact, nitroglycerin, the following tests may be conducted. Whenever possible, testing, neutralization, and disposal of nitroglycerin should be conducted by an expert in the field of explosives.

Although the presence of nitroglycerin is usually suggested by the circumstances, there are several tests which the field investigator may use to confirm his suspicions. For any of the following tests only fractions of a drop of this material should be used, since the explosion of a full drop could remove an eye or a finger.

(1) **Burning** – A small amount smeared on a piece of paper will flare up and produce a puff of white to yellowish smoke when burned.

(2) **The "Anvil" Test** – A match stick is dipped in the suspect liquid and then streaked across an anvil, hammer, or other solid metal object. The smear is then struck sharply with a hammer at one end of the smear. Nitroglycerin will produce a "crack" similar to the sound of a toy pistol cap when struck in this way. Several blows may be required along the length of the smear.

(3) **The "Water" Test** – A drop of the suspect liquid, if nitroglycerin, will sink to the bottom of a container of water.

(4) **Diphenylamine Test** – A drop of a solution of diphenylamine (1%) in 80% sulphuric acid will produce an instant blue color when added to a smear of nitroglycerin. This test is also given by many other substances and is therefore not specific. A negative test does rule out nitroglycerin.

(5) **Laboratory Analysis** – For court purposes, two or three drops of the liquid should be preserved for laboratory analysis. This can be safely transported by dissolving it in about 1 oz. of alcohol or acetone in the original container.

Figures 48-54 present a limited summary of certain selected technical characteristics of common explosives which would be of interest to public safety personnel.

Rate of Detonation	Bullet Impact Sensivity	Detonation Temp (Cent)	Reaction with Metals	Hygroscopic	Stability in Storage	Solvent	Remarks
	100	300	None	Very	Good if Sealed	Water	Most Dangerous Explosive
	0	500	None	Yes	Poor	Acetone	
	0	400	None	No	Poor	Acetone	
17,500	100	245	Forms Sensitive Salts w/Copper	Slight	Good	Acetone	Very Sensitive to Heat, Shock, Friction, and Static Electricity
16,800	100	180	None	No	Good	Acetone	Very Sensitive to Heat, Shock, Friction, and Static Electricity
16,500	100	180	Copper & Brass Wet, Aluminum Dry	No	Poor	Acetone, Pyradine Ammonia	Very Sensitive to Heat, Shock, Friction, and Static Electricity
27,500	100	197	None	No	Good	Acetone, Phenol	Most Powerful, Highest Rate.
24,000	100	172	Slight Corrosion w/Brass	No	Good	Acetone	Pure PETN is White, Addition of Desensitizers May Change Color
17,300	100	180	Unknown	Yes	Good	Acetone, Ammonia, Ether	Very Sensitive to Heat, Shock, Friction, and Static Electricity
24,000	95	164	Slight Corrosion of Steel,–Dry	No	Good	Acetone, Benzene	Most Common Military Booster
23,400	24	300	Forms Dangerous Salts w/Most Metals	Slight	Good	Alcohol Acetone	
22,500	0	288	None	No	Good	Alcohol Ether Acetone	Standard for Most Military Test, Most Common Military High Explosive
23,000	48	185	None	No	Good	Acetone	
22,000	49	254	Corrodes Brass & Steel	Slight	Poor	Acetone	
21,000	48	254	Corrodes, Steel, Brass, Bronze	Very	Poor	Acetone Water	
19,700	0	254	Forms Dangerous Salts w/Tin, Copper	Very	Poor	Acetone	
18,040	21-36	292	None	No	Good	Acetone	Burns Violently, May Detonate if Confined
24,500	20	188	Corrodes Most Metals	No	Good	Acetone	
26,000	0-25	172	None	No	Good	Acetone	
26,000	20	197	Unknown	No	Good	Acetone	Most Insensitive High Explosive
24,500	92	174	Corrodes Most Common Metals	No	Poor	Acetone	
24,500	35	179	Corrodes Most Common Metals	No	Good	Acetone	
21,300	0-30	288	Forms Explosive Salts w/All Metals	Yes	Poor	Alcohol Water	Second Most Insensitive
15,000	90	190	Corrodes Iron & Copper		Poor	Acetone	Very Susceptible to Spontaneous Combustion
Unknown	0	Unknown	None	Yes	Excellent in Pouch	Water	More Powerful Than 75% Dynamite. Not an Explosive Until Mixed.
6,500 Ft Per Sec. to 27,000 Ft Per Sec.	0	Unknown	Copper, Brass, Steel	Yes	Good	Water	Causes Spontaneous Ignition with Tetryl. Can be Poured into Ground or Cracks.
20,368 Ft Per Sec.	0	Unknown	Do Not Mix w/ Any Foreign Metal Powder	No	Good	Unknown	Personnel Should Wear Rubber Gloves when Handling.

ıre 49
⅄ION EXPLOSIVES

NITROGLYCERIN AND AMMONIUM NITRATE DYNAMITES

Nitroglycerin and ammonium nitrate mixed dynamites are brown in color, have a very low detonation temperature and are hydroscopic. They maintain fair stability in storage and are soluble in acetone or water. Replacing a portion or all of the nitroglycerin with ammonium nitrate makes a dynamite which is safer to handle and lower in cost than straight dynamite.

Brand Name	Manufacturer	Fromula or Composition	Primary Use	Rate of Detonation in Feet Per Second	Packaging	Size
"Red Cross Extra"	DuPont	20-35% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	8,000-9,500	Cartridge	See Note 1
"Red Cross Extra"	DuPont	40-50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	10,200-11,200	Cartridge	See Note 1
"Red Cross Extra"	Dupont	60% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	12,000	Cartridge	See Note 1
"Extra"	DuPont	20-25% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	8,800-8,900	Cartridges and 12 1/2, 25-lb. Bags	See Note 2
"Extra"	DuPont	30% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	9,000	Cartridges and 12 1/2, 25-lb. Bags	See Note 2
"Extra"	DuPont	35-45% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	9,300-9,900	Cartridges and 12 1/2, 25-lb. Bags	See Note 2
"Extra"	DuPont	50-55% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	10,500-10,800	Cartridges and 12 1/2, 25-lb. Bags	See Note 2
Hi-Cap 1	DuPont	25% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarry Work, Stump Blasting, Mudcapping	7,000	Cartridges and 12 1/2, 25-lb. Bags	See Note 3
Hi-Cap 2	DuPont	30% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stripping Operations Quarries, Open Pit Mines	8,000	Cartridges and 12 1/2, 25-lb. Bags	See Note 3
Hi-Cap 3	DuPont	40% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stripping Operations, Quarries, Open Pit Mines	8,500	Cartridges and 12 1/2, 25-lb. Bags	See Note 3
Hi-Cap 4	DuPont	50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stripping Operations, Quarries, Open Pit Mines	9,000	Cartridges and 12 1/2, 25-lb. Bags	See Note 3
Standard	Apache	15% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	7,200	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	20% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	7,800	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	25% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	7,900	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	30% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	8,200	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	33% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	8,400	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	35% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Stump Blasting, Agricultural Purposes	8,900	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	40% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Soft Rock, Quarries	9,500	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown

Note: 1: 1", 1 1/8", 1 1/4", 1 1/2", 2" x 8"; 2 1/2", 3", 4" x 16"; 5" x 18".
2: 7/8" to 2" x 8"; 1 1/8", 1 1/4", 1 1/2", 1 3/4", 2 1/2", 3" x 12"; 16", 20", 24".
3: 1", 1 1/8", 1 1/4", 1 1/2", 1 3/4", 2" x 8".

Figure 50
NITROGLYCERIN AND AMMONIUM DYNAMITE

NITROGLYCERIN AND AMMONIUM NITRATE DYNAMITES (CONTINUED)

Brand Name	Manufacturer	Formula or Composition	Primary Use	Rate of Detonation in Feet Per Second	Packing	Size
Standard	Apache	50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Soft Rock, Quarries	11,200	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Standard	Apache	60% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Soft Rock, Quarries	12,800	Cartridges and 12 1/2-lb. Bags	1 1/4" x 8" Other Sizes Unknown
Gas Well Explosive	Hercules	68% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Gas Wells	Unknown	Cartridge	5" x 5 1/2 Ft. 4" x 5 1/2 Ft.
Hercol 2	Hercules	50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Underground, Quarries, Construction Work	10,500	Cartridge	7/8" to 3 1/2" x 8"
Hercol 4	Hercules	35% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Underground, Quarries, Construction Work	9,500	Cartridge	7/8" to 3 1/2" x 8"
Hercol 6	Hercules	20% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Underground, Quarries, Construction Work	8,850	Cartridge	7/8" to 3 1/2" x 8"
Hercol	Hercules	45% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Underground, Quarries Construction Work	6,550	Cartridge	4" Dia and Larger
Hercomite 2 thru 7	Hercules	20-50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	General Blasting	7,850-11,500	Cartridge	All Sizes
Hercomite 2X thru 7X	Hercules	20-50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Underground Work	7,850-11,500	Cartridge	All Sizes
Hercomite 2A thru 7A	Hercules	20-50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	General Blasting	6,400-8,200	Cartridge	All Sizes
Hercomite 2-XA thru 7-XA	Hercules	20-50% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Minimum Fume Work	6,400-8,200	Cartridge	All Sizes
Hercomite-B	Hercules	46% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Open Work Blasting	6,550	Cartridge	All Sizes
Extra	Atlas	20-60% Nitroglycerin/Ammonium Nitrate/Wood Pulp/Sodium Nitrate	Quarries, Construction, Agricultural Work	7,000-10,000	Cartridge	See Note 4
Ammodyte	Atlas	26.2-47% Nitroglycerin/ Ammonium Nitrate/Wood Pulp/ Sodium Nitrate	Quarries, Construction, Underground Mines	9,200-11,000	Cartridge	See Note 4

Note: 4: 1 1/2" x 8; 1 3/4", 2", 2 1/2" x 24"; 2 1/2" x 16"; 3" x 8 1/3"; 3 1/2" x 10 lbs.; 4", 4 1/2" x 16 2/3 lbs.; 5", 5 1/2", 6", 6 1/2" x 25 lbs.; 7", 8" x 50 lbs.

Figure 50
NITROGLYCERIN AND AMMONIUM DYNAMITE (Continued)

GELATIN DYNAMITES

Gelatin dynamites are yellow in color, have a low detonation temperature, and are soluble in acetone. It has poor stability in storage, because it gives off poisonous fumes and must be well ventilated. Gelatin dynamite does not react with metals and is not hydroscopic.

Brand Name	Manufacturer	Formula or Composition	Primary Use	Rate of Detonation in Feet Per Second	Packaging	Size
DuPont Gelatin	DuPont	20-60% Nitroglycerin/ Collodian Cotton	Demolition	10,500-19,700	Cartridges	1¼" x 8", Other Sizes Unknown
DuPont Gelatin	DuPont	75-90% Nitroglycerin/ Collodian Cotton	Demolition	20,600-22,300	Cartridges	1¼" x 8", Other Sizes Unknown
DuPont Gelatin	DuPont	100% Nitroglycerin/ Collodian Cotton	Deep Well Shooting Cutting, Blasting Steel	Unknown	Cartridges	1¼" x 8", Other Sizes Unknown
Hi-Velocity Gelatin	DuPont	40-60% Nitroglycerin/ Collodian Cotton	Submarine Work	16,700-19,700	Cartridges	1¼" x 8", Other Sizes Unknown
Hi-Velocity Gelatin	DuPont	70-90% Nitroglycerin/ Collodian Cotton	Submarine Work	20,300-22,000	Cartridges	1¼" x 8", Other Sizes Unknown
Special Gelatin	DuPont	25-80% Nitroglycerin/ Collodian Cotton	Construction Work	13,100-17,100	Cartridges	See Note 1
Apache Gelatins	Apache	20-100% Nitroglycerin/ Collodian Cotton	Construction Work	11,400-23,600	Cartridges	1¼" x 8", Other Sizes Unknown
Hercules Gelatin	Hercules	40% Nitroglycerin/ Collodian Cotton	Underwater Blasting	18,000	Cartridges	See Note 1
Oil Well Explosive	Hercules	100% Nitroglycerin/ Collodian Cotton	Oil Wells	Unknown	Cartridges	2" x 8" and Larger
Power-Gel	Hercules	30% Nitroglycerin/ Collodian Cotton	Construction Work	16,500	Cartridges	1¼" x 8", Other Sizes Unknown
High Pressure Gelatin	Hercules	60% Nitroglycerin/ Collodian Cotton	Construction Work	19,700	Cartridges	1¼" x 8" and Larger
Gelatin Extra	Hercules	40% Nitroglycerin/ Collodian Cotton	Construction Work	18,000	Cartridges	See Note 1
Gelatin Extra	Hercules	60% Nitroglycerin/ Collodian Cotton	Construction Work	21,300	Cartridges	See Note 1
Gelatin Extra	Hercules	75% Nitroglycerin/ Collodian Cotton	Construction Work	23,000	Cartridges	See Note 1
Giant Gelatin	Atlas	30-90% Nitroglycerin/ Collodian Cotton	Quarry, Mining, Construction, River Crossings, Ditching	10,500-21,000	Cartridges	See Note 2

Note: 1: 7/8", 1", 1 1/8", 1 1/4", 1 1/2", 2" x 8"; 2 1/2", 3", 4" x 16"; 5" x 24".
2: 1 3/4", 2", 2 1/2" x 24"; 2 1/2" x 16"; 3" x 10 lbs; 3 1/2" x 10 lbs; 4", 4 1/2" x 16 2/3 lbs; 4 1/2", 5", 5 1/2", 6" x 6 1/2" x 25 lbs; 7" x 50 lbs; 8" x 50 lbs.

Figure 51
GELATIN DYNAMITES

PERMISSIBLE/PERMITTED DYNAMITES

Permissible or permitted dynamite has approximately 10% salt added to reduce flame and reduce fumes; all are approved by the Bureau of Mines. Generally they have poor stability in storage, low detonation temperatures, and are hydroscopic.

Brand Name	Manu-facturer	Formula or Composition	Primary Use	Rate of Detonation in Feet Per Second	Packing	Size
C-X-L-ite	C-I-L	Unknown %, but Similar to Normal Dynamite with Salt Added	Rock Work in Coal Mines	16,000	Cartridge	1 1/4" x 8", Other Sizes Unknown
Doubel "A"	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	9,200	Cartridge	1 1/4" x 8", Other Sizes Unknown
Doubel "B"	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	9,000	Cartridge	1 1/4" x 8", Other Sizes Unknown
Doubel "C"	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	8,800	Cartridge	1 1/4" x 8", Other Sizes Unknown
Doubel "D"	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	8,400	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel AA	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	9,000	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel A	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	7,400	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel B	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	7,000	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel C	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	6,500	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel D	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	6,200	Cartridge	1 1/4" x 8", Other Sizes Unknown
Monobel E	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coarse Coal	6,050	Cartridge	1 1/4" x 8", Other Sizes Unknown
"Lump Coal" C	Dupont	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting for Large Lump Coal	5,800	Cartridge	1 1/2" Smallest Diameter
"Lump Coal" CC	DuPont	Unknown %, but Similar to Normal Dynamite with Salt Added	Thin Seam Coal Blasting	5,700	Cartridge	1 1/4" x 8", Other Sizes Unknown
"Gelobel" AA	DuPont	Similar to Gelatin Dynamite Has Salt Added	Rock Work in Coal Mines	16,500	Cartridge	1 1/4" x 8', Other Sizes Unknown
"Gelobel" C	DuPont	Similar to Gelatin Dynamite, Has Salt Added	Rock Work in Coal Mines	12,100	Cartridge	1 1/4" x 8", Other Sizes Unknown
Coalite 5	Atlas	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	6,200-8,700	Cartridge	1 1/8", 1 1/4", 1 1/2", 1 3/4", 2" x 8"
Pearless 2Z	Atlas	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting in Coal	8,000	Cartridge	1 1/8", 1 1/4", 1 1/2", 1 3/4", 2" x 8"
Gelcoalite	Atlas	Unknown %, but Similar to Normal Dynamite with Salt Added	Blasting Rock	13,300-17,000	Cartridge	1 1/8", 1 1/4", 1 1/2", 1 3/4", 2" x 8"

Figure 52
PERMISSIBLE/PERMITTED EXPLOSIVES

SEMI-GELATIN DYNAMITES

Semi-gelatin dynamite is brown in color, has a low detonation temperature and is not hydroscopic. It is soluble in acetone, has poor stability in storage and is very sensitive when frozen. Semi-gelatin dynamite may have little or no nitroglycerin.

Brand Name	Manufacturer	Formula or Composition	Primary Use	Rate of Detonation in Feet Per Second	Packaging	Size
Special Gelatin	DuPont	25-80% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction Work, Quarries, Mining	13,100-17,100	Cartridge	See Note 1
Gelex 1	DuPont	60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction, Tunneling, Quarry, Mining, and Underground Work	13,100	Cartridge	See Note 1
Gelex 2	DuPont	45% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction, Tunneling, Quarry, Mining, and Underground Work	12,600	Cartridge	See Note 1
Gelex 3	DuPont	40% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction, Tunneling, Quarry, Mining, and Underground Work	12,000	Cartridge	See Note 1
Gelex 4	DuPont	35% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction, Tunneling, Quarry, Mining, and Underground Work	11,800	Cartridge	See Note 1
Gelex 5	DuPont	30% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction, Tunneling, Quarry, Mining, and Underground Work	11,300	Cartridge	See Note 1
Toval	DuPont	Unknown %, Nitroglycerin/ Wood Pulp/ Collodian Cotton/ Wood Meal	Construction, Quarry, Open Pit Mines	13,000	Cartridge	See Note 2
Toval 2	DuPont	Unknown %, Nitroglycerin/ Wood Pulp/ Collodian Cotton/ Wood Meal	Construction Work	12,500	Cartridge	See Note 2
Gelamite 1 thru 5	Hercules	30-60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction Work	9,850-12,500	Cartridge	See Note 1
Gelamite 1-X thru 5-D‡	Hercules	30-60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Underground Work	9,850-12,500	Cartridge	1", 1 1/8", 1 1/4", 1 1/2", 1 3/4" x 8"
Gelamite D‡	Hercules	65% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction Work	17,700	Cartridge	See Note 1
Special Gelatins	Apache	30-90% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Construction Work	13,100-19,700	Cartridge	1 1/4" x 8". Other Sizes Unknown
Amogel 1 thru 5	Apache	30-60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry and Mining	10,500-14,100	Cartridge	1 1/4" x 8", Other Sizes Unknown
Amogel B, C, and D	Apache	40-60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry and Open Pit Mining.	10,000-12,000	Cartridges and 12 1/2 lb. Bags	4" Thru 10" Dia.
Iremite 40	Ireco	40% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry and Open Pit Mining Construction Work	11,000	Cartridges	1 1/4", 1 1/2", 2", 2 1/2", 3" x 24"
Iremite 60	Ireco	60% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry and Open Pit Mining Construction Work	11,500	Cartridges	1 1/4", 1 1/2", 2", 2 1/2", 3" x 24"
Iremite 80	Ireco	80% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry and Open Pit Mining Construction Work	12,500	Cartridges	1 1/4", 1 1/2", 2", 2 1/2", 3" x 24"
Gelodyn No. 1	Atlas	52% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry, Tunnel Work, Metal Mining, General Construction	14,000	Cartridges	See Note 3
Gelodyn No. 3	Atlas	46.8% Nitroglycerin/Wood Pulp/ Collodian Cotton/Wood Meal	Quarry, Tunnel Work, Metal Mining, General Construction	15,000	Cartridges	See Note 3

Note: 1: 1", 1 1/8", 1 1/4", 1 1/2", 2" x 8"; 2 1/2", 3" x 16".
2: 1 1/4" x 8"; 1/2", 1 3/4" x 12"; 2" x 24"; 2 1/2", 3", 3 1/2" x 16"; 5" x 18"; 5" x 24".
3: 1 1/2" x 8"; 1 3/4", 2", 2 1/2" x 24"; 2 1/2" x 16"; 3" x 8 1/3 lbs; 3 1/2" x 10 lbs; 4", 4 1/2" x 16 2/3 lbs; 5", 5 1/2", 6", 6 1/2" x 25 lbs; 7", 8" x 50 lbs.

Figure 53
SEMI-GELATIN DYNAMITES

DETONATING CORD

Other Name: Primacord, Detacord

Commercial Name	Filler	Construction and Color
Detacord Ensign Bickford	18 grains PETN per foot	PETN core surrounded by textile and covered with plastic jacket. Color: Yellow with one blue strand.
E-Cord Ensign Bickford	25 grains PETN per foot	PETN core encased in textile braid covered with plastic, then outer textile yarns cross-countered, one red and one blue identifying strands. Color: Yellow base, with red and blue strands.
T-Line Primex Apache	30 grains PETN per foot	PETN core encased in braided textile, covered by plastic and finish. Color: Hi-Glo orange.
Economy Primex Apache	30 grains PETN per foot	PETN core encased in braided textile covered by plastic and finish. Color: Hi-Glo orange with one green thread.
Reinforced Primex Apache	50 grains PETN per foot	PETN core encased in braided textile covered by plastic and finish. Color: Hi-Glo orange with 3 green threads. Hi-Glo yellow with 3 green threads.
#54 Plastic Primex Apache	54 grains PETN per foot	PETN core encased in braided textile covered by plastic and finish. Color: Clear white.
Scuf-Flex Ensign Bickford	60 grains PETN per foot	PETN core enclosed in high tenacity textile yarns followed by a heavy plastic jacket, further protected by high strength textile counterings with wax finish. Color: Red.

Figure 54
DETONATING CORD

Commercial Name	Filler	Construction and Color
Tuf-Glo Apache	60 grains PETN per foot	PETN core encased in braided textile covered by plastic and finish. Color: Hi-Glo yellow with two green threads.
PETN 60 Plastic HV Ensign Bickford	60 grains PETN per foot	PETN core encased in textile braid, covered with polyethylene plastic. Color: Clear plastic.
Plastic Wire Countered Primacord Ensign Bickford	60 grains PETN per foot	PETN core encased in textile braid covered with asphalt, steel wire, and red and white rayon yarn countering. Outer jacket polyethylene plastic. Color: Red and white "barber pole."
PETN 100 Plastic Ensign Bickford	100 grains PETN per foot	PETN core enclosed in textile braid, covered with polyethylene plastic. Color: White with clear plastic.
PETN 150 Plastic Ensign Bickford	150 grains PETN per foot	PETN core encased in textile braid, covered with polyethylene plastic. Color: Dark blue.
PETN 175 Plastic Ensign Bickford	175 grains PETN per foot	PETN core encased in textile braid, covered with polyethylene plastic. Color: White with clear plastic.
PETN 400 Plastic Ensign Bickford	400 grains PETN per foot	PETN core encased in textile braid, covered with polyethylene plastic. (Sealed ends.) Color: Light green.
PETN 50 Duplex Ensign Bickford	Two 50 grain cores per foot 100 grain total	Two 50 grain textile covered cores enclosed in polyethylene plastic. Color: Vivid red.

Figure 54
DETONATING CORD (Continued)

Commercial Name	Filler	Construction and Color
RDX 70 Primacord* Black Hycar Ensign Bickford	70 grains RDX per foot	RDX core encased in textile braid, covered by an outer jacket of Hycar. Hycar is a Buna-N synthetic rubber. Color: Pink core, black rubber cover.
80 RDX Nylon Ensign Bickford	80 grains RDX per foot	RDX core encased in textile braid, covered by an outer jacket of nylon. Color: Pink core, black nylon cover.

*RDX: Requires a special booster for initiation. Wet RDX primacord cannot be initiated. Can stand exposure to 350°F for two hours.

Figure 54
DETONATING CORD (Continued)

SECTION THREE

BLASTING ACCESSORIES

Blasting accessories are products or devices used to prepare, test, or initiate explosive charges. Since they are commonly associated with commercial blasting operations and occasionally employed in criminal bombings, these accessories and their uses should be familiar to public safety personnel. While possession of these accessories is not a criminal offense in most jurisdictions, their close association with explosive operations makes their possession under certain circumstances a cause for further inquiry.

BLASTING CAP CRIMPERS

Blasting cap crimpers are used to squeeze the shell of nonelectric blasting caps around safety fuse or detonating cord to prevent separation. The crimper handles act as a screwdriver and a punch. This tool is also equipped with a fuse cutter for the right angle cutting of safety fuse. The blasting cap crimper tool is illustrated in figure 55.

FUSE IGNITERS

Fuse igniters are used to apply sparks or flame to manufactured or improvised "safety" fuse. Of course, a safety fuse can easily be ignited with an ordinary match. When a match is employed, the

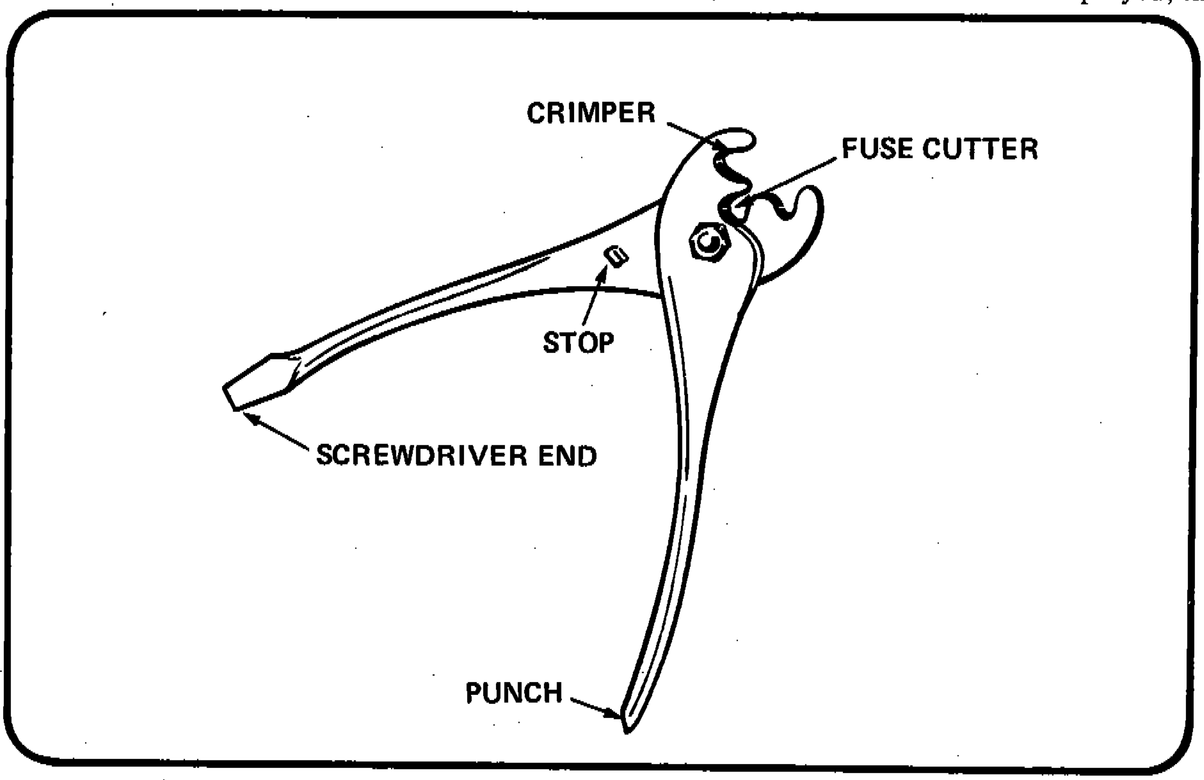

Figure 55
BLASTING CAP CRIMPING TOOL

preferred technique is to split the end of the fuse and insert the head of an unlighted match in the exposed powder train. The inserted match head is then ignited by holding a flaming match to it or by striking the inserted match head with the abrasive side of a match box as shown in figure 56.

On the other hand, operating conditions may require a special device to provide a positive method of lighting safety fuse regardless of weather conditions. Such devices are called *fuse igniters* or *fuse lighters* and they are usually reliable. Certain types, if properly waterproofed, will even function effectively underwater. To aid in more certain ignition, the safety fuse should be cut at a 90 degree angle and fully and firmly inserted into the fuse igniter to assure contact between the spit of fire generated by the igniter and the black powder core of the safety fuse. Several types of commercial and military fuse igniters may be encountered by public safety personnel.

Friction Type Igniters

When using the friction type igniters illustrated in figure 57, the fuse is cut and inserted securely into the open end of the igniter. The handle at the closed end of the igniter is pulled sharply and completely out of the igniter body. Pulling the handle will drag the coated wire through the friction compound and ignite it. The ignition of the friction compound fires the powder train in the fuse.

Percussion Type Igniters

To use the percussion type igniter illustrated in figure 58, the fuse is cut and inserted into the open end of the device which is usually sealed with a small rubber stopper during storage. When the

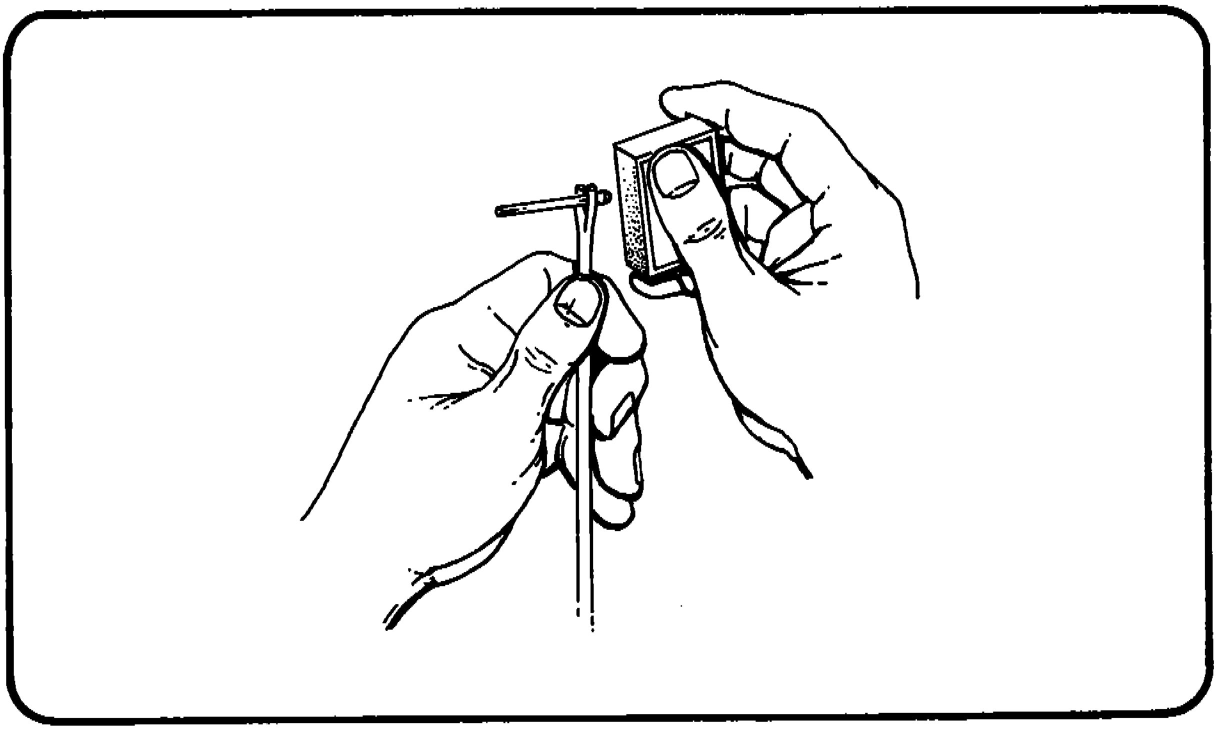

Figure 56
IGNITING SAFETY BLASTING FUSE WITH MATCHES

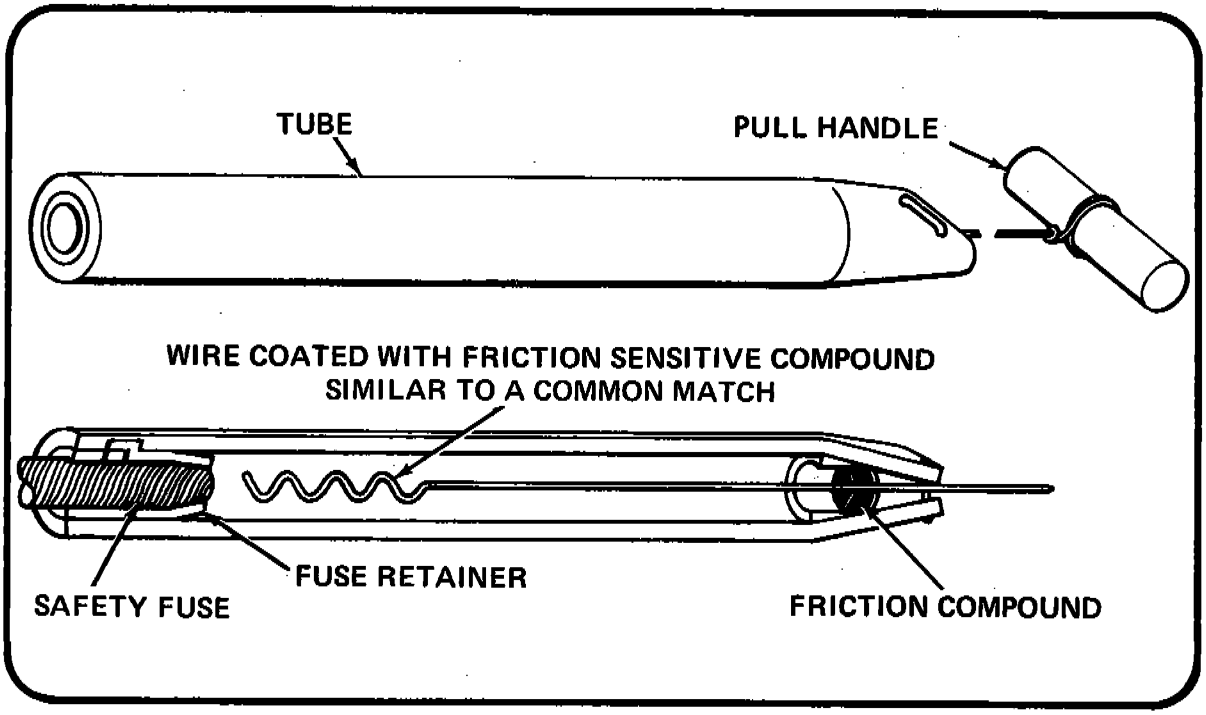

Figure 57
FRICTION TYPE FUSE IGNITER

pull ring of the release pin is pulled, the spring loaded striker is driven by the firing pin spring into the percussion primer, which emits a spit of flame to ignite the powder train in the fuse.

Hot Wire Fuse Lighter

This type of fuse lighter is similar in appearance to a firework sparkler. It consists of a wire, ranging from 7 to 12 inches in length, covered with an ignition composition and is lighted with a match and, in turn, is used to light the safety fuse by holding the burning portion against the cut end of the safety fuse. It can also be used in conjunction with the flame type fuse lighter. Hot wire fuse lighters burn with an intense heat at a steady rate.

Flame Type Fuse Lighters

An example of a flame type fuse lighter is illustrated in figure 59. The fuse lighter is crimped onto the safety fuse, and a hot wire fuse lighter or the flame from a burning match is applied inside the slot of the top section of the lighter.

Thermalite Ignitacord

Thermalite ignitacord is used for igniting safety fuse when firing blastholes in rotation. It is cordlike in appearance, approximately 1/16 inch in diameter, and burns progressively along its

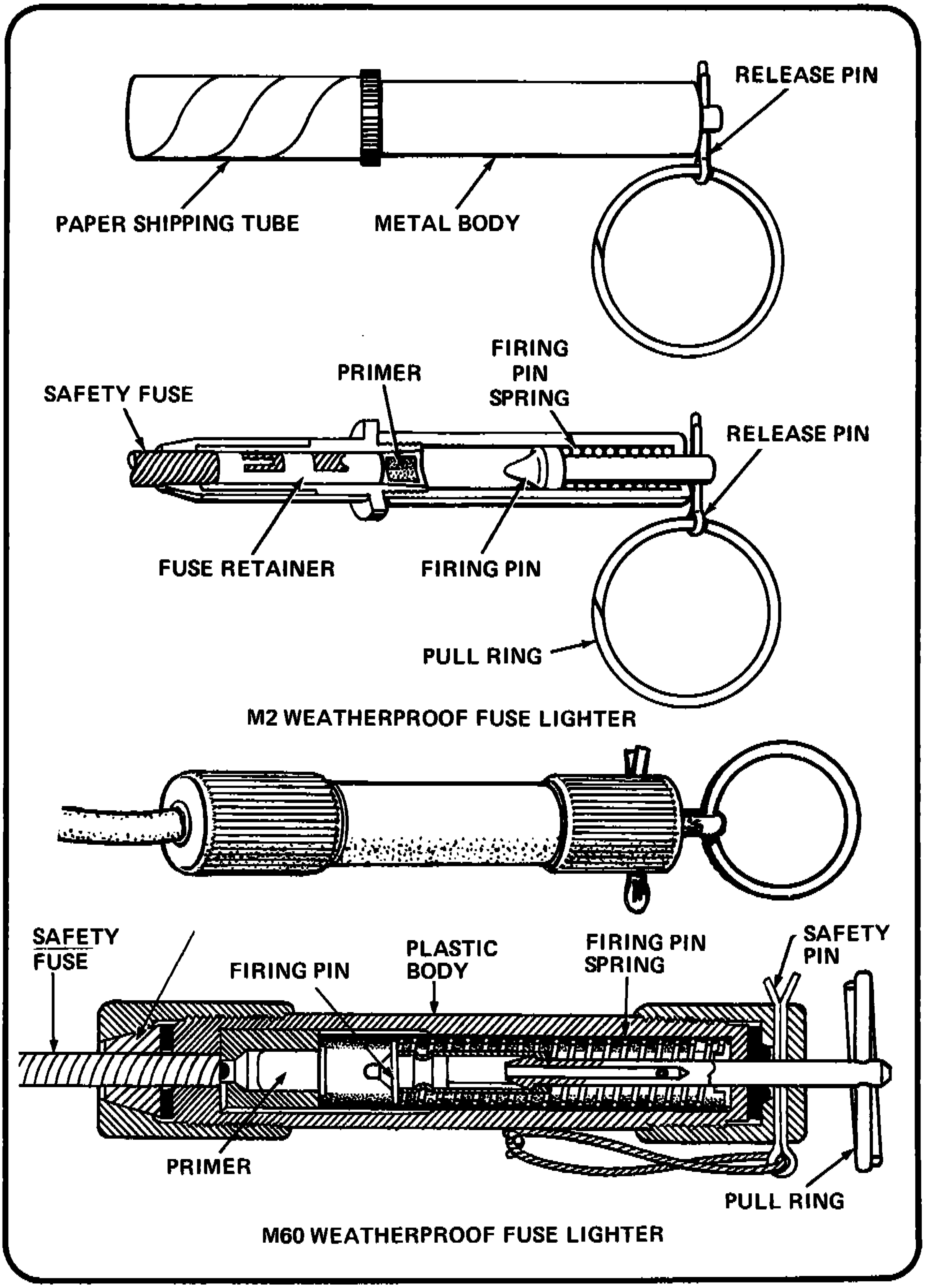

Figure 58
PERCUSSION FUSE IGNITERS

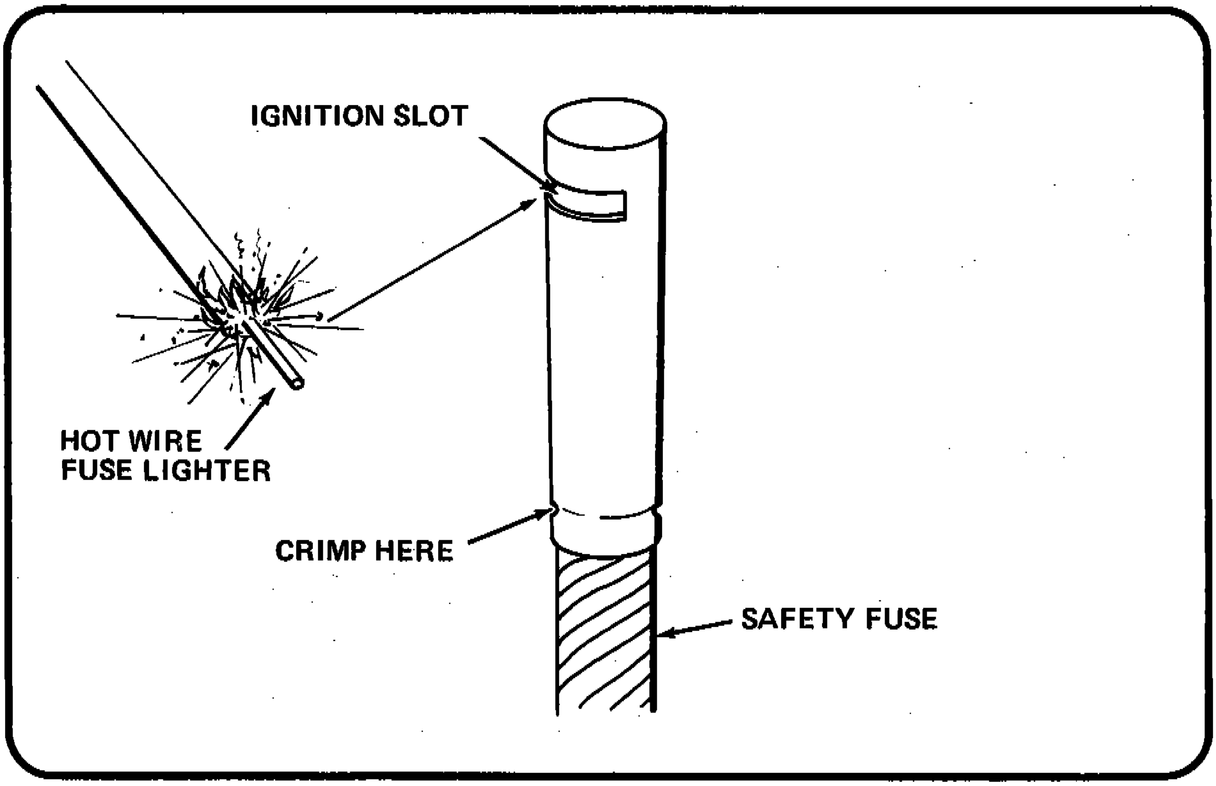

Figure 59
HOT WIRE FUSE LIGHTER AND FLAME TYPE FUSE LIGHTER

length with an external flame at the zone of burning. Ignitacord is inserted into a slot in a metal fuse lighter attached to the safety fuse. When the ignitacord burns through this slot, as illustrated in figure 60, it ignites the safety fuze. Ignitacord is available in three different burning speeds: 4, 8, and 16 seconds per foot. It is packaged in 33 1/3-foot packages or on 100-foot rolls.

Improvised Igniters

Bombers have devised a method of assuring a more positive ignition of their improvised safety fuse by dipping the ignition end of the fuse in a type of liquid ignition mixture such as quick-drying household or airplane cement and allowing it to dry. When flame from a match is applied to this dried ignition mixture, it produces a very hot flame to assure fuse ignition.

POWDER IGNITER

Electric Squibs (Igniters)

Electric squibs, also known as *electric matches,* are used primarily for initiating low explosives where a burning action is desired. Electric squibs resemble electric blasting caps and consist of an aluminum or copper shell approximately 1 inch long and about the size of a pencil in diameter. Some squibs come with plastic or paper capsules for use where metal fragments are to be avoided.

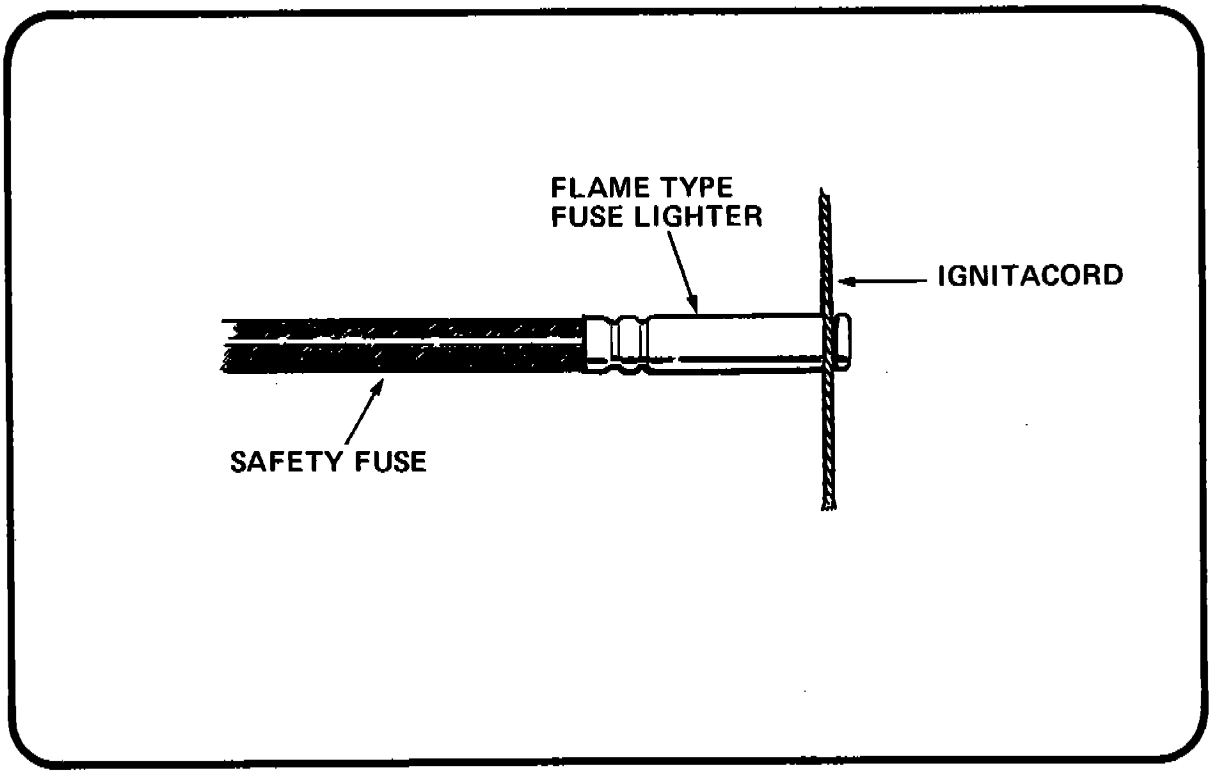

Figure 60
THERMALITE IGNITACORD INSERTED IN
IGNITION SLOT OF FLAME TYPE FUSE LIGHTER

There are two types of squibs: vented and unvented. Unvented squibs rupture and vented squibs, shown in figure 61, produce flame through preformed openings or vent holes. Both types of squibs contain an ignition composition at one end and an electric bridge wire at the other. When current is applied, the bridge wire ignites the ignition mixture which causes an intense flame to issue from the ruptured shell or through vent holes in the shell. This flame ignites the black powder.

FIRING WIRE

Any wire capable of carrying electrical current from a power source to the bridge wire of an electric blasting cap may be employed as firing wire. This wire is used to provide the blaster with a safe distance between his point of initiation and the immediate area in which the detonation occurs. Military and commercial firing cable is normally obtainable in lengths of 500 and 1,000 feet and is two-conductor, insulated, and normally Number 18 AWG (gage). Resistance of each conducter is approximately 5 ohms or less per 1,000 feet for commercial wire and 10 ohms or less per 1,000 feet for military wire. For convenience in handling, firing wire is generally mounted on some form of reel or drum as illustrated in figure 62.

Communications wire may also be used as firing wire. However, it has a resistance of about 40 ohms per 1,000 feet, which increases the amount of electrical power necessary to fire the charge. An example of an electrical blasting circuit is illustrated in figure 63. Frequently, the firing wire and

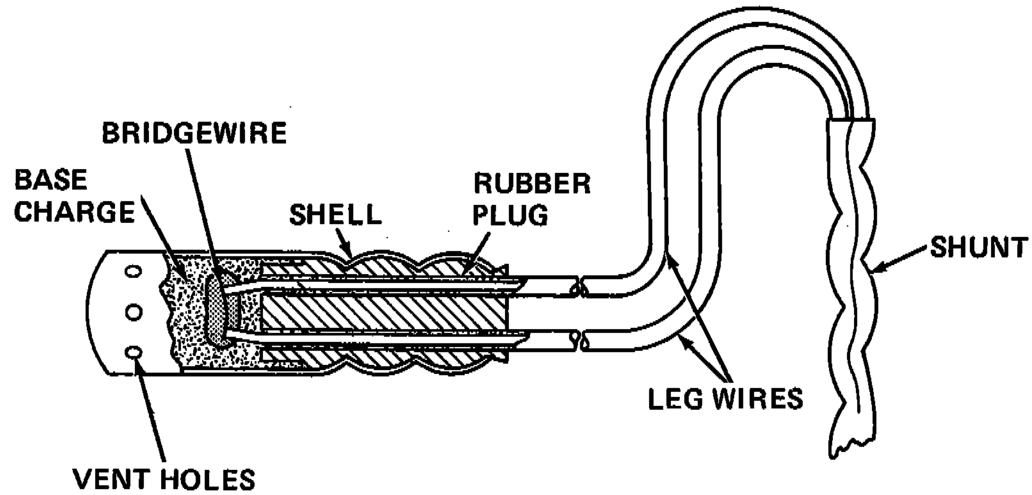

Figure 61
TYPICAL VENTED ELECTRIC SQUIB

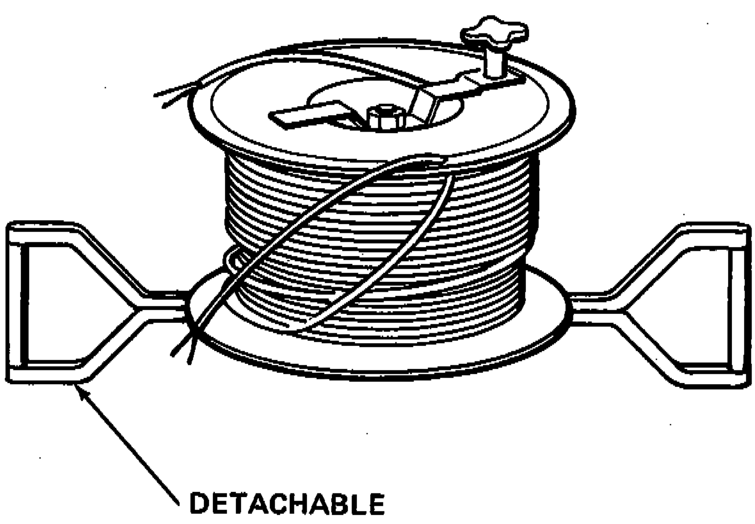

Figure 62
REEL OF FIRING WIRE

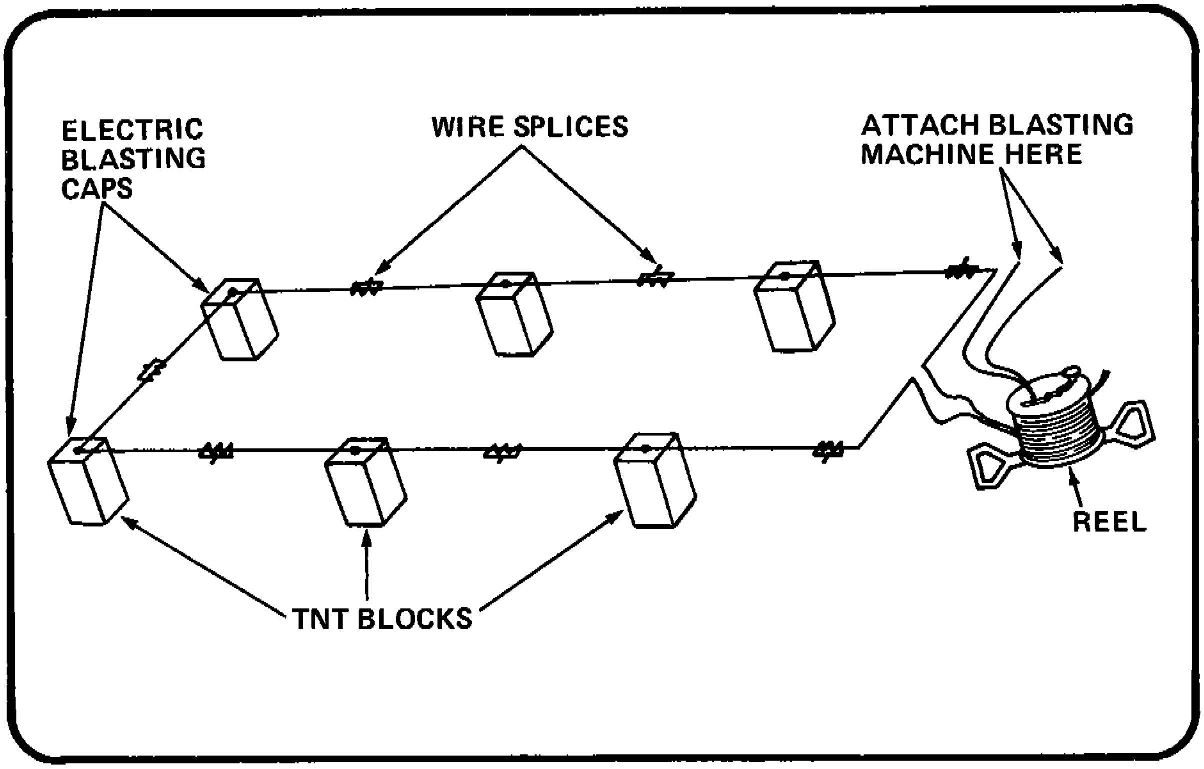

Figure 63
SIX CHARGES CONNECTED IN SERIES TO BE FIRED ELECTRICALLY. THE REEL OF FIRING WIRE CAN BE ROLLED OUT TO A SAFE DISTANCE AND THE FIRING WIRE CONNECTED TO THE TERMINALS OF THE BLASTING MACHINE.

electric blasting cap lead wires will be found somewhere in the area of the detonation, unless they have been retrieved.

BLASTING MACHINES

A blasting machine is a device designed to deliver a current directly into an explosive firing circuit. This is accomplished either by converting physical or mechanical actions into electrical energy or by the use of batteries, generators, or capacitors.

Miniature Blasting Machines

Model 7107-7. This model with a 120-volt output can fire an electric blasting cap through 3,000 feet of Number 18, two-conductor, firing wire or ten electric blasting caps in straight series through 1,800 feet of wire.

Model 7107-4. With a 300-volt output, this model can fire a single electric blasting cap through 10,000 feet of Number 18, two-conductor, copper wire or fifty electric blasting caps in straight series through 3,600 feet of wire. Both models are illustrated in figure 64.

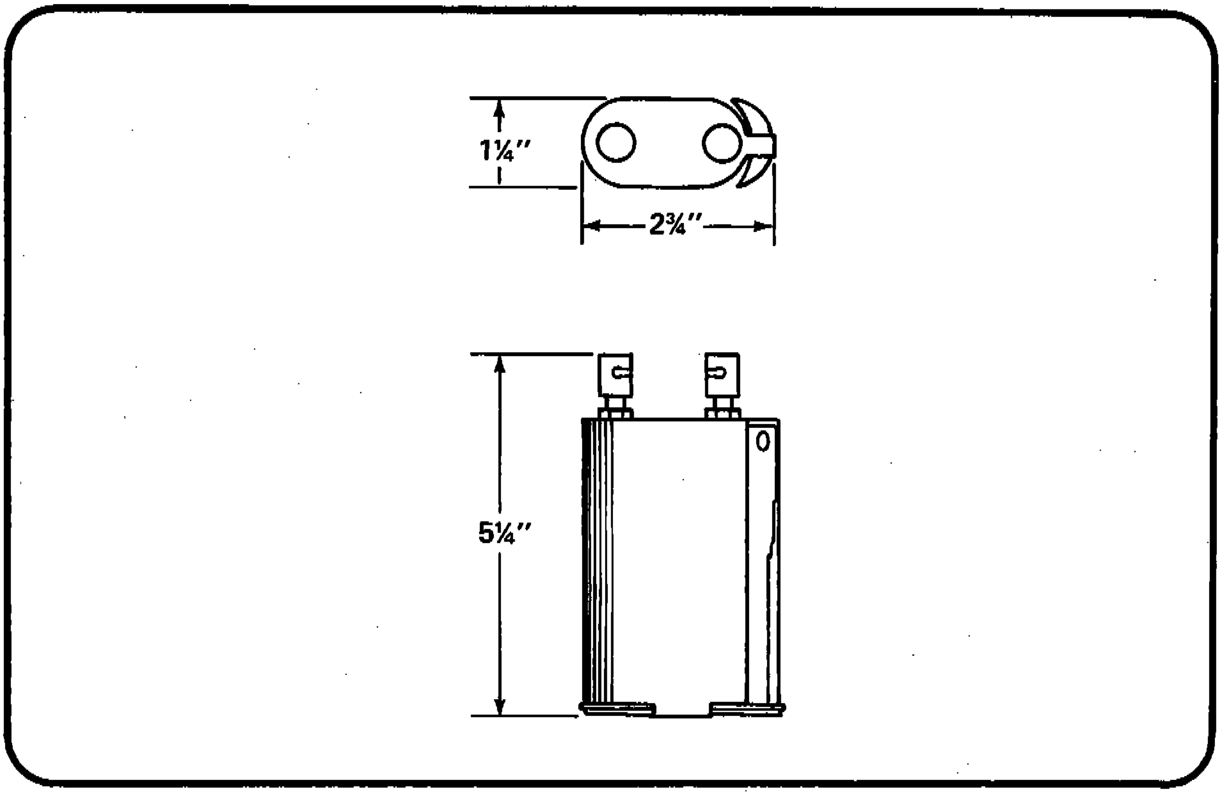

Figure 64
EXTERNAL DIMENSIONS OF THE MODEL 7107-7 AND MODEL 7107-4 MINIATURE BLASTING MACHINES. NOTE THAT THEY BOTH HAVE THE SAME DIMENSIONS. THEY ALSO WEIGH THE SAME: 12 OUNCES.

The model 7107-7 and 7107-4 miniature blasting machines can be operated in one hand, by grasping and squeezing the handle along one side of the machine once or twice. This action spins an alternator at speeds up to 15,000 r.p.m., and the alternator output is rectified and used to charge the energy storage capacitors. The voltage builds up until the voltage required to fire the caps is reached. Both models are manufactured by Unidynamics, 472 Paul Avenue, St. Louis, Mo. 63135.

Mini-Blaster. The Mini-Blaster is a battery operated blasting machine slightly larger than a pack of cigarettes and weighing only 15 ounces. It measures 4 1/4 by 2 3/8 by 1 3/8 inches. The electrical output is 1 1/2 amps for 10 msec at 20 ohms resistance, which allows it to fire 20 electric blasting caps in series. The electrical power source is two 22 1/2-volt photoflash batteries. The Mini-Blaster, illustrated in figure 65, has an orange fiberglass reinforced case, a waterproof firing switch and a yellow "fire ready" indicator light. This small compact blasting machine will fire over 10,000 individual shots without requiring a battery change and is used in all types of explosive work. The Mini-Blaster is manufactured by Explosives Corporation of America, Excoa Building, Issaquah, Washington 98027.

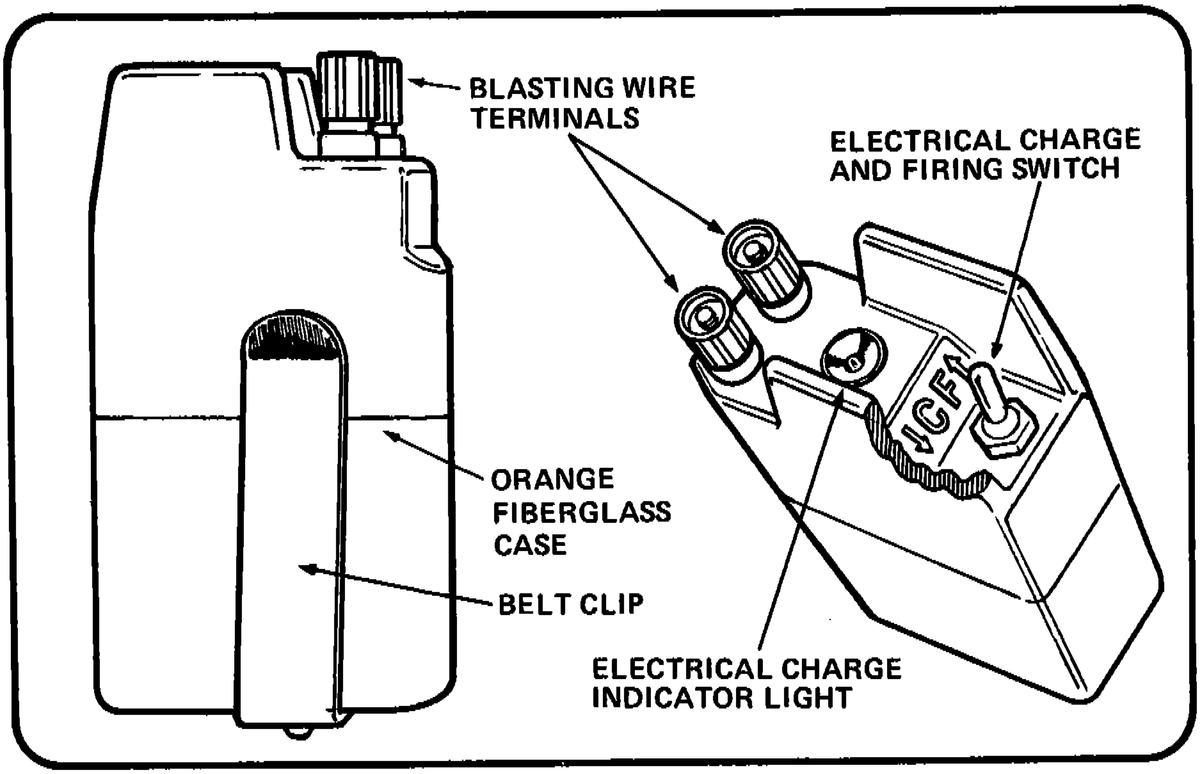

Figure 65
MINI-BLASTER

Ten-cap Twist Blasting Machine

For small blasting operations, a 10-cap blasting machine is widely used in commercial and military operations. This machine, which is illustrated in figure 66(A), is a hand-operated, twist type and is limited to 10 caps in a series. Prior to assembling a primed charge into the firing circuit, the handle should be twisted several times to test and insure free movement of the generator. The handle is spring loaded to return to its neutral position when pressure is released. When ready to fire, the two ends of the firing wire are each wired to one of the terminals of the blasting machine. The handle of the machine is vigorously twisted in a clockwise direction, driving the generator to fire the electric blasting caps.

Plunger Type Blasting Machine

For larger blasting operations, a plunger type machine, illustrated in figure 66(B), is generally used. Plunger type machines are made in three different sizes to fire 30, 50, and 100 caps in series. However, all of the machines function in exactly the same manner. The electrical cables, which are attached to an electrically primed explosive assembly, are wired to the two terminals of the blasting machine. To fire, the blasting machine handle is raised to the limit of its travel, then vigorously thrust down to the lower limit of travel. The downward motion of the gear-toothed shaft drives the generator, creating sufficient electrical energy to fire the blasting caps.

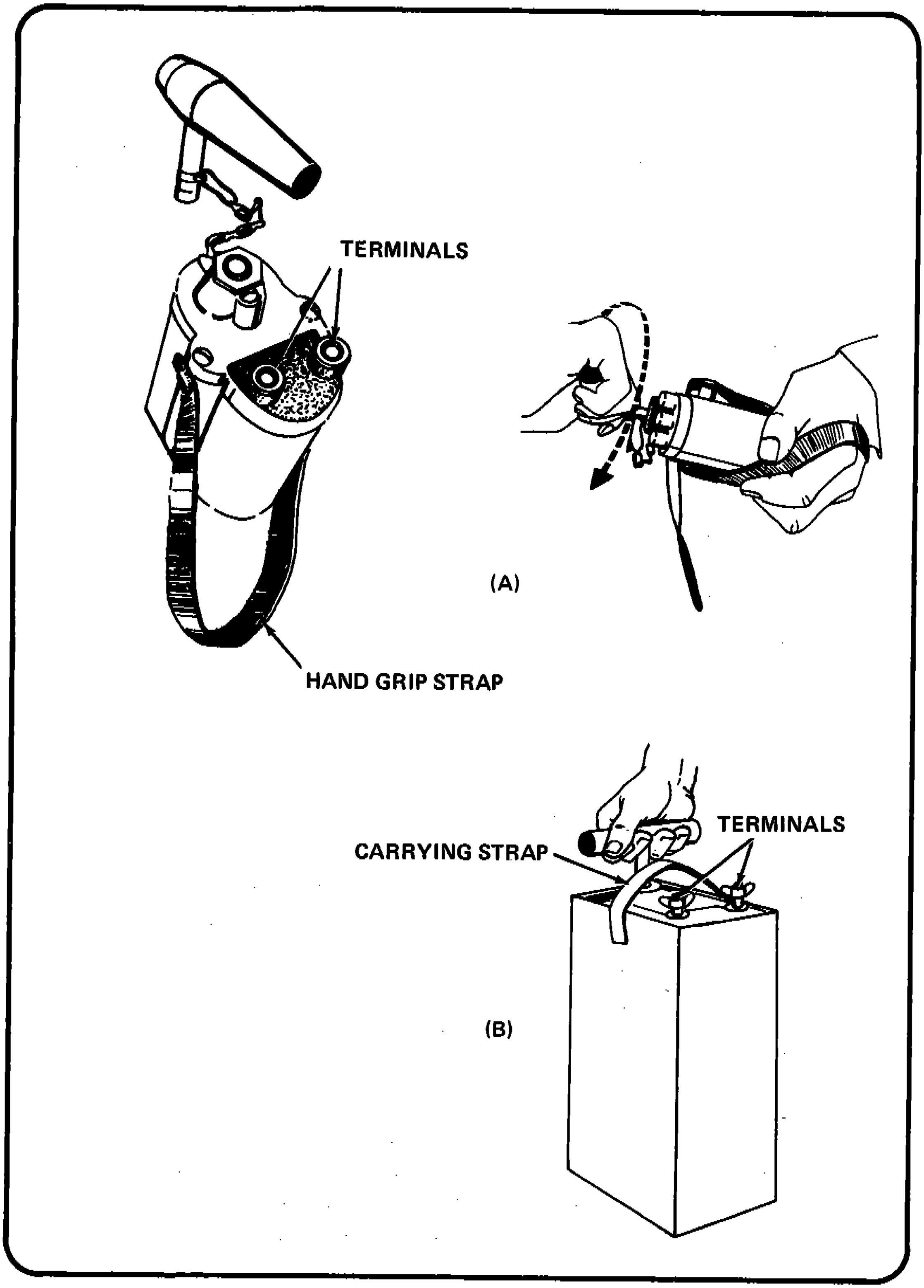

Figure 66
TWIST TYPE (A) AND PLUNGER TYPE (B) BLASTING MACHINES

Improvised Blasting Machines

While bombers very seldom utilize blasting machines to remotely fire their charges, they have hooked up their charges to the electrical system of automobiles and have also employed dry cell batteries as a source of power to fire their devices. Any battery of sufficient size can be employed to supply electric current to a blasting cap.

GALVANOMETERS

The blasting galvanometer is an electrical assembly which is used to test the electrical continuity of a firing circuit. There is a possibility of poor, weak, dirty, or broken connections when the components of an electrical blasting circuit are wired together. Therefore, it is a normal practice to test an electrical circuit's continuity before any attempt is made to fire it. A galvanometer is normally constructed of an electromagnet, an indicator needle, a graduated scale, and a battery. Of utmost importance is the source of power, which should be sufficient to indicate continuity, but *insufficient to initiate the blasting caps.*

While both military and commercial galvanometers employ silver chloride batteries as their source of power, commercial types normally include limiting resistors in their operating circuits to preclude excess applied voltages. In military galvanometers, *ONLY* the special silver chloride dry cell battery BA 254/U should be used. This particular battery produces 0.9 volts, which is sufficient for positive testing of blasting circuitry, but insufficient to initiate a blasting cap. A typical galvanometer is illustrated in figure 67.

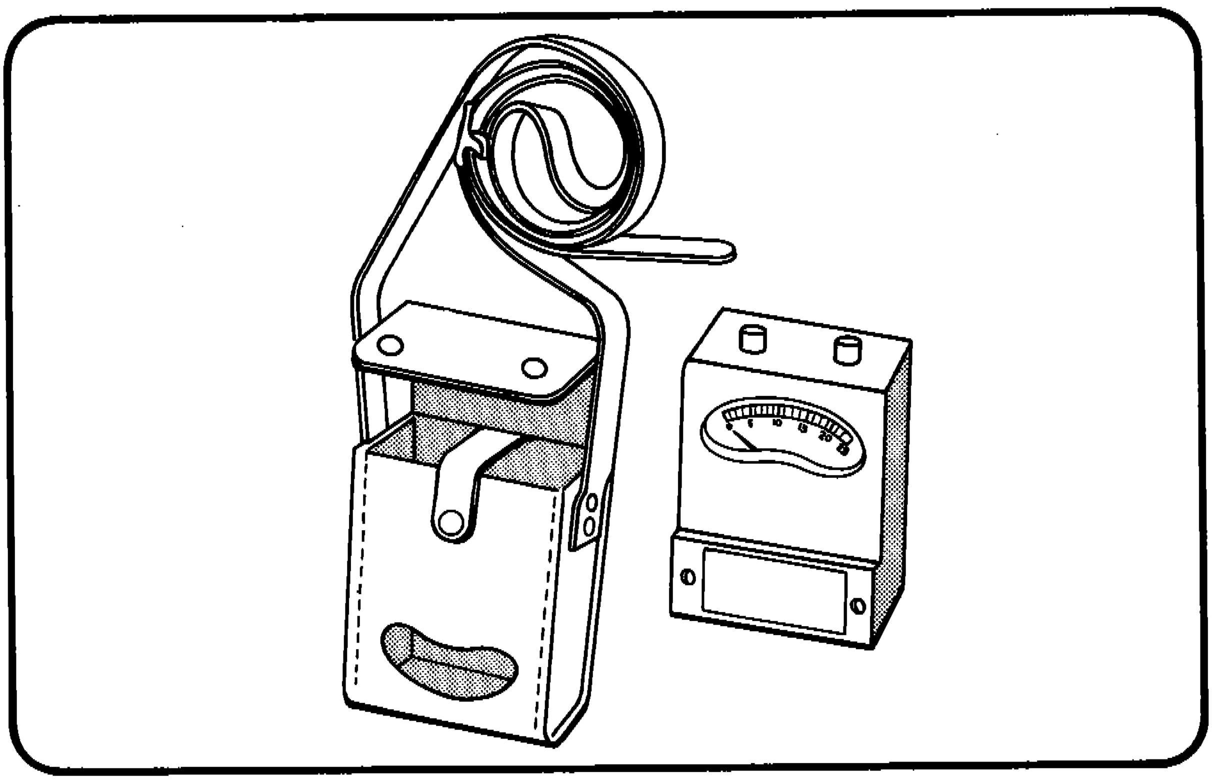

Figure 67
GALVANOMETER AND CARRYING CASE

Improvised galvanometers may be manufactured by assembling a battery and a small indicator lamp or inexpensive ohm meter. However, these devices are limited to testing continuity of the firing wire assembly only. *DO NOT TEST WITH A BLASTING CAP IN THE CIRCUIT.* An improvised galvanometer is illustrated in figure 68.

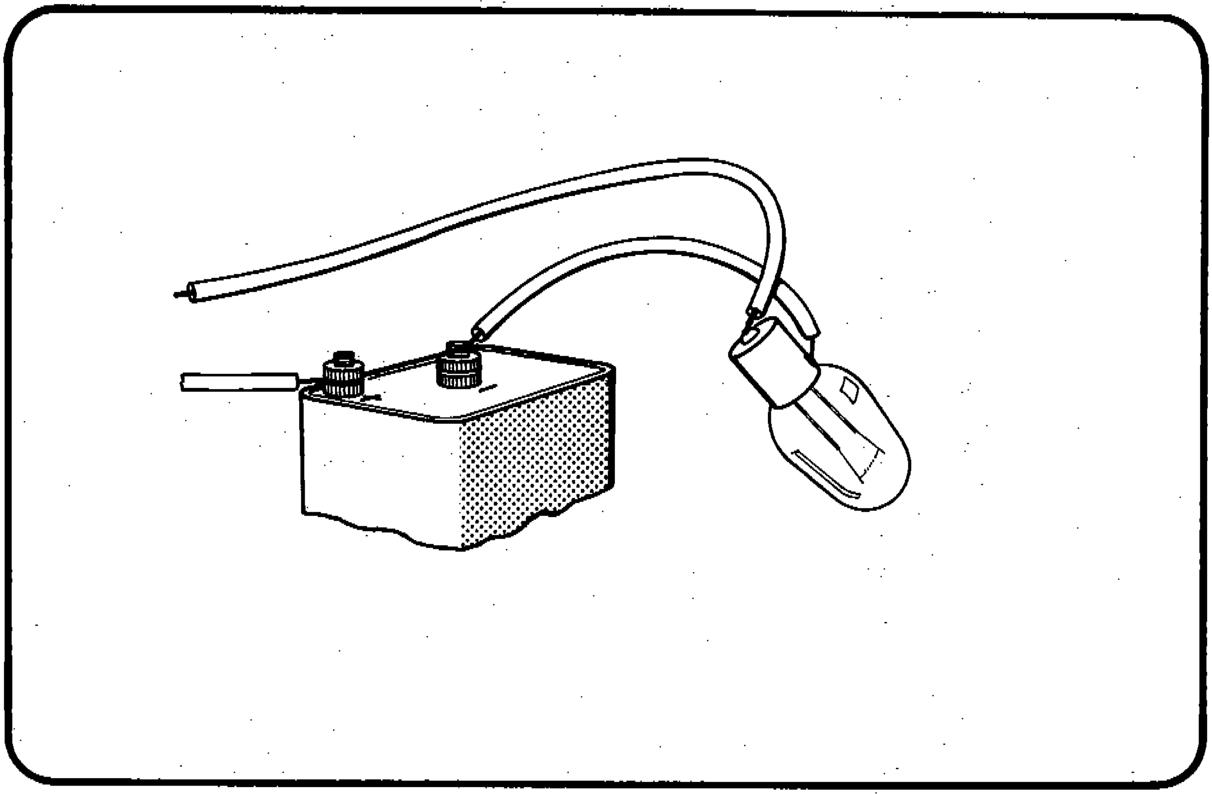

Figure 68
IMPROVISED "GALVANOMETER"

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This is a draft document. Recommendations for changes, additions, and deletions are welcome and should be forwarded to:

The National Bomb Data Center
International Association of Chiefs of Police
11 Firstfield Road
Gaithersburg, Maryland 20760