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DEPARTMENT OF THE ARMY FIELD MANUAL

EXPLOSIVES AND DEMOLITIONS

HEADQUARTERS, DEPARTMENT OF THE ARMY

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EXPLOSIVES AND DEMOLITIONS

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CHAPTER 1
EXPLOSIVES AND SPECIAL CHARGES

Section I. INTRODUCTION

1. Purpose and Scope

a. This manual is a guide in the use of explosives for the creation and demolition of military obstacles and in certain construction projects. The material includes information on—

(1) Types, characteristics, and uses of explosives.

(2) Preparation, placement, and firing of charges.

(3) Calculation formulas.

(4) Deliberate and hasty demolition methods appropriate for use in the forward zone.

(5) Handling, transportation, and storage of explosives.

(6) Safety precautions.

b. The contents of this manual are applicable to nuclear and nonnuclear warfare.

2. Comments

Users of this manual are encouraged to submit comments or recommendations for changes for improvement. Comments should be referenced to the specific page, paragraph, and line of text, and reasons for each comment given to insure proper understanding and evaluation. Comments should be forwarded direct to the Commandant, U.S. Army Engineer School, Fort Belvoir, Va.

3. Military Demolitions

Military demolitions are the destruction by fire, water, explosive, and mechanical or other means, of areas, structures, facilities, or materials to accomplish the military objective. They have offensive and defensive uses, for example, the removal of enemy barriers to facilitate the advance, and the construction of friendly barriers to delay or restrict enemy movement.

Section II. EXPLOSIVES

4. Definitions

a. Explosives. Explosives are substances that through chemical reaction violently change and release pressure and heat equally in all directions. Explosives are classified as low or high according to the speed (feet per second) with which this change takes place.

b. Low Explosive. Low explosives *deflagrate* or change from a solid to a gaseous state relatively slowly over a sustained period. This quality makes the low explosive ideal for pushing or shoving a target. Examples are the smokeless and black powders that change from the solid to the gaseous state at relatively slow rates.

c. High Explosive. The change in this type of explosive to a gaseous state—detonation—occurs almost instantaneously, producing a shattering effect upon the target. Detonation rates range from 3,281 feet to 27,889 feet per second. High explosives are used where this shattering effect is required—in certain demolition charges and in charges in mines, shells, and bombs.

5. Characteristics of Military Explosives

Explosives used in military operations possess certain properties or characteristics essential to their function. In the past, many explosives have been studied for possible military use; but the requirements are such that less than a score have proved satisfactory for standardization. The essential characteristics of military explosives are—

a. Relative insensitivity to shock or friction; and not liable to detonation by small arms fire.

b. Proper detonating velocity.

c. High power per unit of weight.

d. High density (weight per unit of volume).

e. Sufficient stability to retain usefulness for a reasonable time in storage in any climate.

f. Positive detonation by easily prepared primers.

g. Suitability for underwater use.

h. Convenient size and shape to facilitate packaging and logistics and handling by troops.

i. Capability over a wide range of temperatures.

6. Selection of Explosives

The explosives satisfactory for military purpose are generally selected on the basis of velocity of detonation. For example, an explosive having a high detonating velocity is generally used for cutting and breaching; that of a lower velocity, for cratering, ditching, and quarrying. The types commonly used are described below.

7. TNT (Trinitrotoluene)

Trinitrotoluene (fig. 1), commonly known as TNT is one of the least sensitive of military high explosives. It is reasonably stable in any climate, does not readily absorb water, and is quite stable

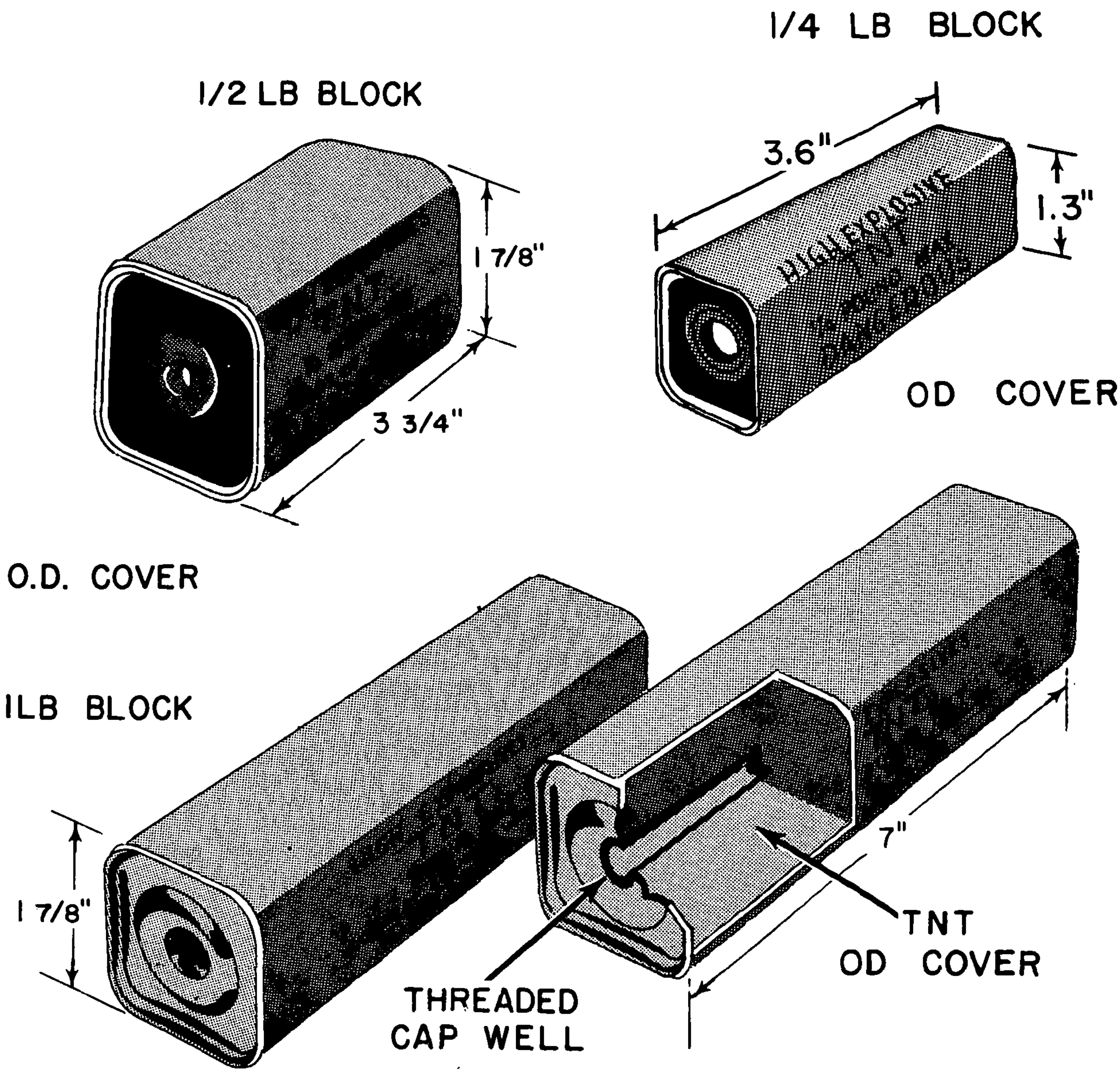


Figure 1. TNT blocks.

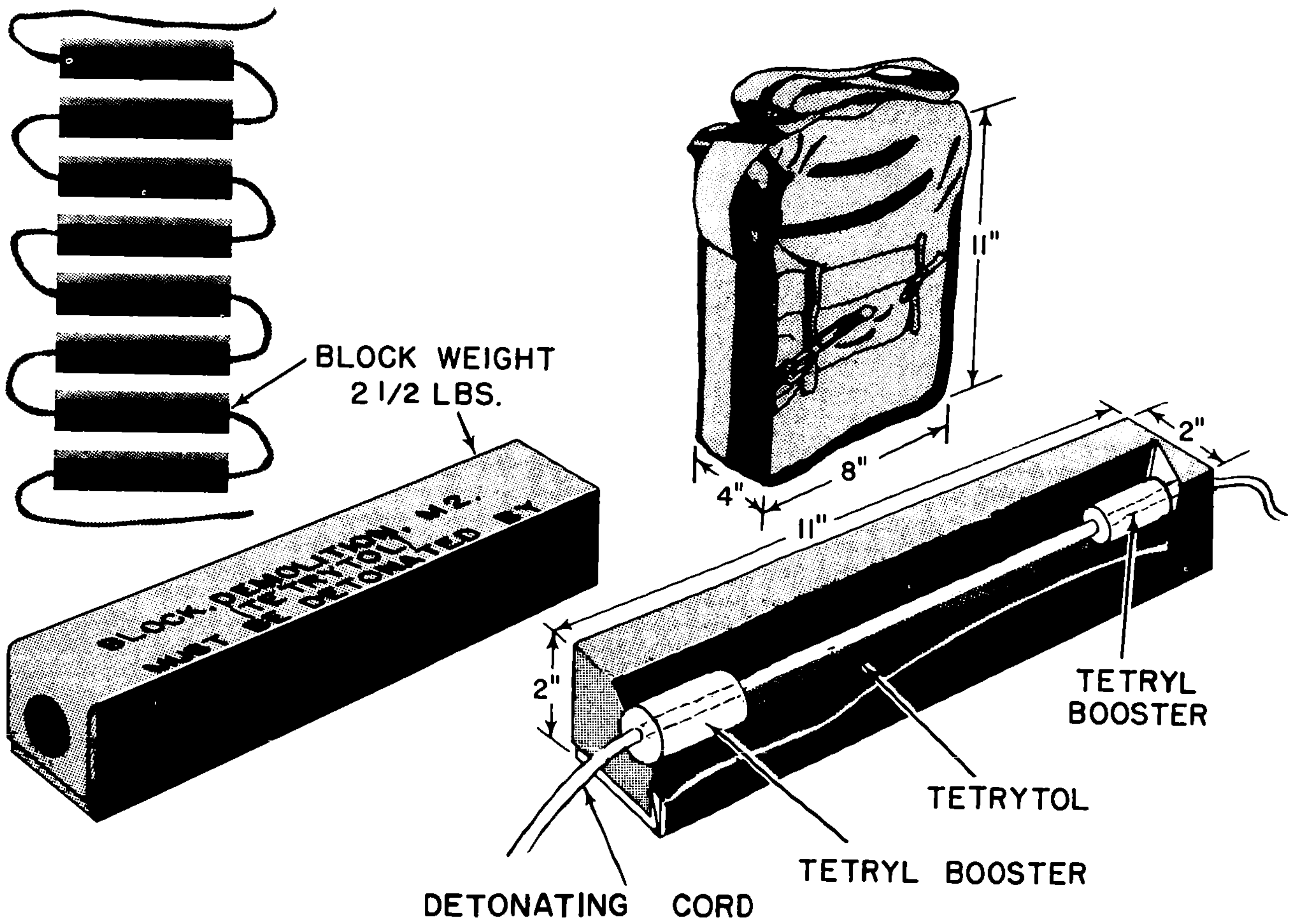


Figure 2. M1 chain and M2 demolition blocks.

in closed storage. The detonation rate is 21,000 feet per second.

a. Packaging. TNT is packaged in ¼-pound, ½-pound, and 1-pound blocks.

(1) The ¼-pound blocks are in an olive drab cardboard container with metal ends. One end has a threaded cap well. Two hundred blocks are packed in a wooden box.

(2) The ½-pound blocks are in a yellow or olive drab cardboard container with metal ends. The yellow container has an unthreaded cap well and the olive drab container, a threaded cap well. One hundred blocks are packed in a wooden box.

(3) The 1-pound blocks are merely two ½-pound blocks in an olive drab cardboard container with metal ends. One end has a threaded cap well. Priming adapters and the standard base of firing devices fit these threads. Fifty 1-pound blocks are packed in a wooden box.

b. TNT is used primarily in cutting and breaching operations.

c. Detonation. Military electric or nonelectric blasting caps and PETN detonating cord, or any of the firing devices having a military cap attached may be used to detonate TNT.

8. Tetrytol (M1 Chain Demolition Block)

Demolition block M1 has all the desirable characteristics of TNT and is slightly more powerful, having a detonation rate of 23,000 feet per second. It is thus more effective as a cutting or breaching charge. It is only slightly soluble in water and is brittle, breaking very easily when dropped (fig. 2).

a. Packaging. Each block is 11 inches long by 2 inches square and weighs 2½ pounds. A tetryl pellet is cast into the block near each end. Eight blocks, spaced 8 inches apart, are cast lengthwise onto a single line of detonating cord, 2 feet of which is left free at each end of the chain. Each block is inclosed in an olive drab asphalt-impregnated paper wrapper. One chain (8 blocks) is packed in an olive drab cloth haversack with a carrying strap attached. The complete bag measures 4 by 8 by 11 inches and weights about 22 pounds. It contains 20 pounds of explosive. Two chains are packed in a wooden box.

b. Use. The M1 chain demolition block may be used in forward combat areas as an alternate to TNT. The complete chain, or any part of the chain, may be laid out in a line, wrapped around a target, or used in the haversack as it is packed. The entire chain will detonate, even though the blocks may not be in contact with each other. If less than eight blocks are needed, the required number is cut from the chain. Each block must have 8 inches of detonating cord attached.

c. Detonation. Tetrytol is detonated by the military electric or nonelectric blasting cap. It may also be detonated by PETN detonating cord and any of the firing devices having the military blasting cap attached.

9. Tetrytol (M2 Demolition Block)

The M2 demolition block is similar to the M1 chain block except that it has a threaded cap well in each end but has no core of detonating cord. The M2 demolition block measures 11 by 2 by 2 inches. A booster tetryl pellet, cast into the block, surrounds each cap well.

a. Packaging. Eight blocks, 2½ pounds each, are packed in a haversack; and two haversacks, in a wooden box.

b. Use. The M2 demolition block is used in the same manner as the M1 block for cutting and breaching. Chains may be made by connecting blocks with detonating cord.

10. Composition C3 (M3 or M5 Demolition Block)

Composition C3 (fig. 3) is a yellow, odorous, plastic explosive more powerful than TNT. In normal temperature its sensitivity compares with that of TNT. At temperatures below minus 20° F., it becomes hard and brittle; at temperatures above 120° F., it becomes extremely soft and exudes some

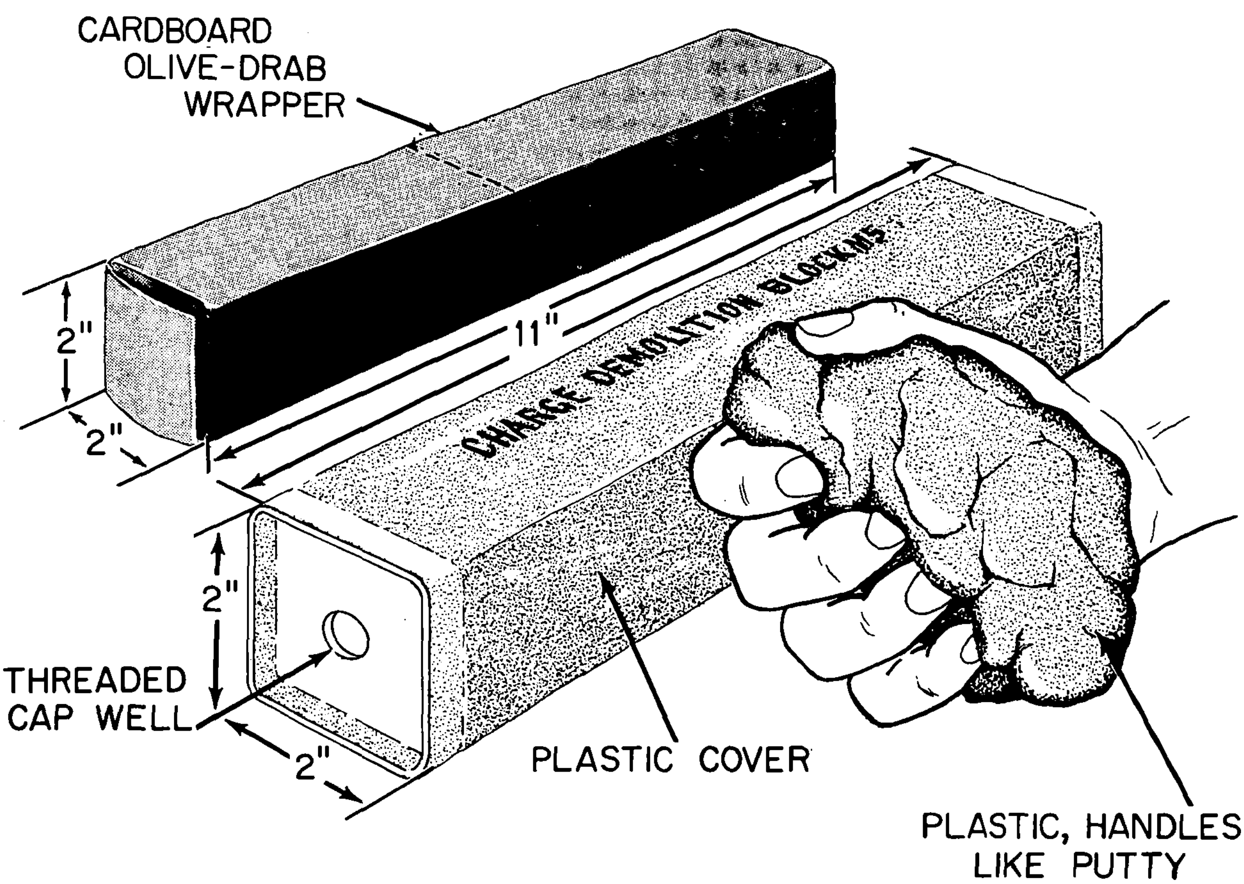


Figure 3. M3 and M5 demolition blocks.

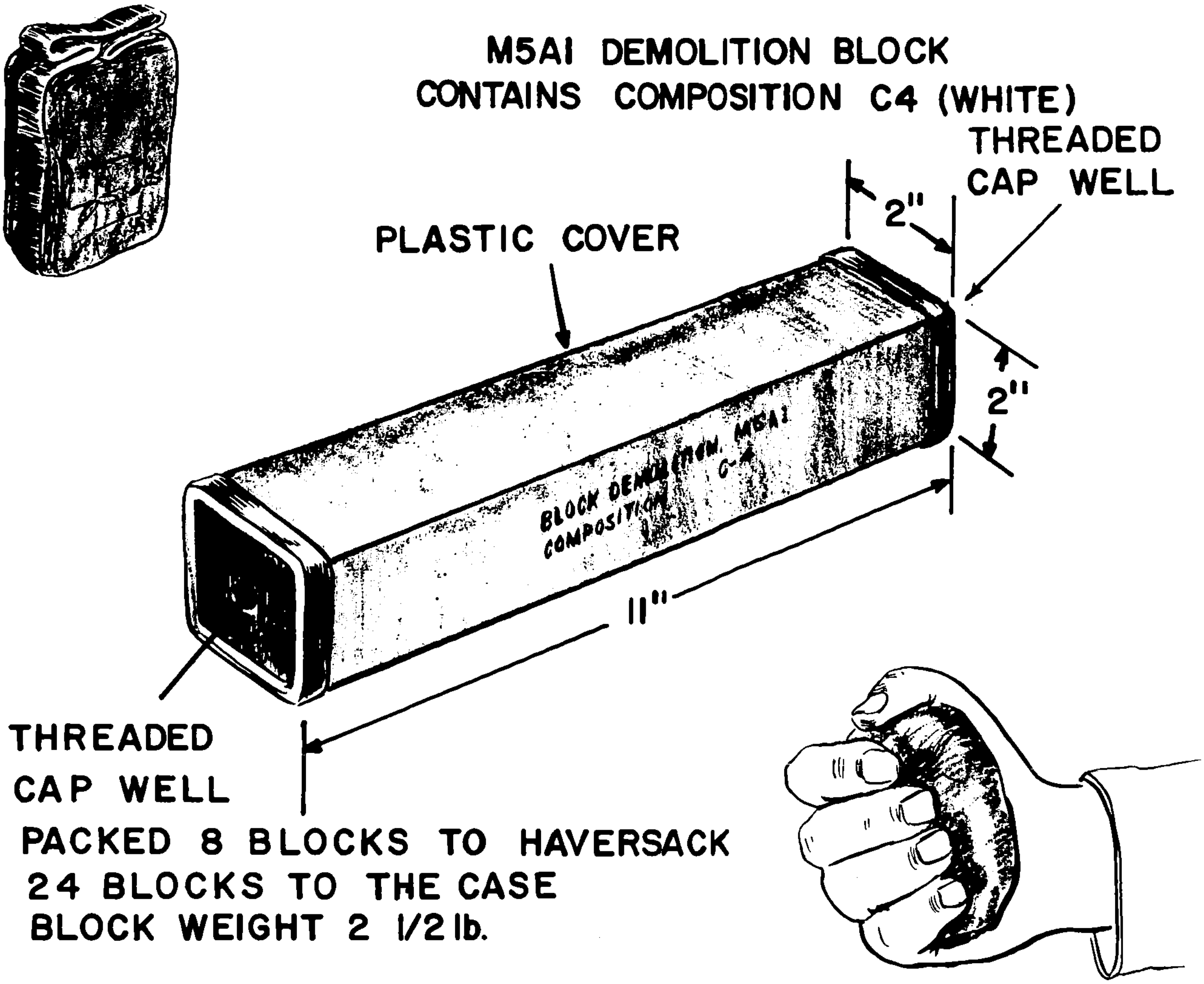


Figure 4. M5A1 demolition block.

of its oils. It is, however, more sensitive than TNT to initiation by impact.

a. Packaging. Composition C3 is packaged as the M3 or M5 demolition block. The M3 block is perforated around the middle to make it easy to break open. Each block measures 11 by 2 by 2 inches and weighs 2¼ pounds. Eight blocks are packed in a haversack and two haversacks are packed in a wooden box. The M5 demolition block has a plastic container with a threaded cap well. Each block measures 11 by 2 by 2 inches and weighs 2½ pounds.

b. Uses. Because of its plasticity and high detonation velocity (26,000 fps), Composition C3 is ideally suited to cutting steel structural members. It is easily molded in close contact to irregularly shaped objects and is an excellent underwater charge if enclosed in a container to prevent erosion.

c. Detonation. Composition C3 may be detonated with the military blasting cap, electric or nonelectric; detonating cord; or any of the firing devices with the military blasting cap attached.

11. Composition C4 (M5A1 Demolition Block)

This is a white plastic explosive, more powerful than TNT and without the order of plastic C3. It remains plastic over a wide range of temperatures (−70° F., to 170° F.), and is about as sensitive as TNT. It has many advantages over C3. It is less sticky than C3 and will not adhere as much to the hands. It erodes less than other plastic explosives when immersed underwater for long periods (fig.4).

a. Packaging. C4 is packaged as a block explosive measuring 11 by 2 by 2 inches and weighing 2½ pounds. Each block is wrapped in a plastic covering with a threaded cap well at either end for use as a block explosive. Twenty-four blocks are packed in a wooden box. Bulk Composition C4, like bulk Composition C3, is obtained by breaking open and removing the wrapper.

b. Uses. Because of its high detonation velocity and its plasticity, Composition C4 is well suited for cutting steel and timber and breaching concrete. It may be used as an underwater charge, if inclosed in the original or an improvised container to prevent erosion by stream currents.

c. Detonation. Composition C4 may be detonated by the military blasting cap, electric or nonelectric; detonating cord; or any of the firing devices with the military blasting cap attached.

12. Composition B

This is a high explosive with a relative effectiveness higher than that of TNT, but more sensitive. Because of its shattering power and high rate of detonation, Composition B is used as the main charge in certain models of bangalore torpedoes and shaped charges.

13. PETN (Pentaerythritetranitrate)

PETN, the explosive used in detonating cord, is one of the most powerful of military explosives, almost equal in force to nitroglycerine and RDX. When used in detonating cord, PETN has a detonation velocity of 21,000 feet per second and is relatively insensitive to friction and shock from handling and transporting.

14. Amatol

Amatol is a mixture of ammonium nitrate and TNT with a relative effectiveness slightly higher than that of TNT. Amatol (80/20) may be found in the bangalore torpedo.

15. RDX (Cyclonite)

RDX is the base charge in the M6 and M7 electric and nonelectric blasting caps. It is highly sensitive and brisant (great shattering effect), probably second only to nitroglycerine.

16. Military Dynamite

Military (construction) dynamite was developed to meet the field troop requirements for a blasting explosive. Unlike commercial dynamite, it does not absorb or retain moisture, contains no nitroglycerine, and is thus much safer to store, handle, and transport. It is packaged in standard cartridge waxed-paper wrappers (fig. 5). Military dynamite (M1) is a standard stick 1¼ by 8 inches and weighs approximately a half-pound. Because it detonates at a velocity of approximately 20,000 feet per second, it is very satisfactory for military construction, quarrying, and other demolition work. It may be detonated by means of the electric or nonelectric military blasting cap or detonating cord.

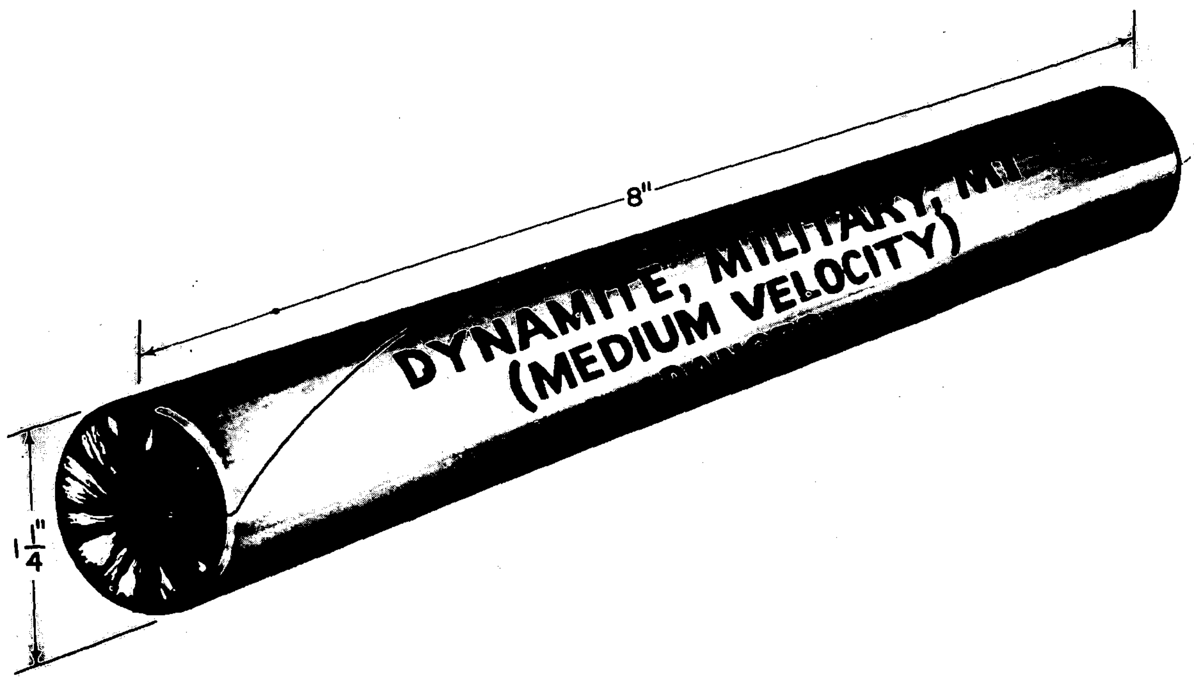


Figure 5. Military dynamite.

17. Commercial Dynamites

These are used in certain rear area military demolitions and construction where special explosives may be required. They include straight, ammonia, and gelatin dynamites. Commercial, straight dynamites are named according to the percentage by weight of nitroglycerine they contain; for example, 40 percent straight dynamite contains 40 percent nitroglycerine. Ammonia dynamite is different, however, as 40 percent ammonia dynamite indicates that the dynamite is as strong as 40 percent straight dynamite but not that it contains 40 percent nitroglycerine by weight.

a. Characteristics. Commercial dynamite is not a standard military explosive because of its undesirable characteristics. It must be handled carefully, as flame, sparks, friction, and sharp blows may detonate it. As commercial dynamite deteriorates rapidly, it requires special care in storage It may be exploded by a No. 6 or larger commercial blasting cap, by military blasting caps, or by detonating cord.

b. Straight Dynamite. This contains nitroglycerine and a nonexplosive filler. Its high velocity of detonation produces a shattering action. Although straight dynamite is water resistant only to a small degree, it may be used underwater if fired within 24 hours after submersion.

c. Ammonia Dynamite. Ammonia dynamite contains ammonia nitrate and nitroglycerine, which is the explosive base. Because of its medium detonating velocity, it produces a heaving action. It is not satisfactory for use underwater.

d. Gelatin Dynamite (Commerical). This explosive is a jelly made by dissolving nitrocellulose in nitroglycerine. Because of its high resistance to water, it is satisfactory for underwater demolitions.

e. Uses. Being sensitive to shock and friction, commercial dynamite is not generally used in forward areas; but it is acceptable in emergencies when other more suitable explosives are lacking. Sixty percent straight dynamite, approximately equal in strength to TNT, has a variety of uses; gelatin dynamite is applicable to underwater demolitions and for land clearing, cratering, and quarrying. A gelatin dynamite of low heaving force and a high rate of detonation is used for blasting hard rock. Available dynamites and their characteristics are described in SM 9-5-1375 and TM 9-1910.

18. Foreign Explosives

a. Types. Explosives used by foreign countries include TNT, picric, and guncotton. Picric acid has characteristics like TNT except that it corrodes metals and thus forms extremely sensitive compounds. A picric acid explosive in a rusted or corroded container must not be used; in fact, it should not be handled in any way, except to move it very carefully to a safe disposal area or location for destruction.

b. Uses. Whenever possible, explosives of allied nations and those captured from the enemy may be used to supplement standard supplies. Such explosives, however, should be used only by experienced soldiers and then only according to instructions and directives issued by theater commanders. Captured bombs, propellants, and other devices may be used with U. S. military explosives for larger demolition projects, such as pier, bridge, tunnel, and airfield destruction (pars. 1–4, app. III. Most foreign explosive blocks have cap wells large enough to receive U. S. military blasting caps. These blasting caps, when used with foreign explosives, should be test fired before extensive use.

Section III. SPECIAL CHARGES

19. Ammonium Nitrate Cratering Charge

Ammonium nitrate is the least sensitive of all military high explosives. It is about half as powerful as TNT. Because of its low velocity of detonation, its shattering power is relatively low. It should be used only in its original metal container as a protection from moisture (fig.6), which quickly destroys its effectiveness.

a. Packaging. Ammonium nitrate cratering explosive is issued as a 40-pound charge in a cylindrical metal container 8¼ inches in diameter and 17 inches high. The container has a cap well and detonating cord tunnel for priming. An integral TNT booster is provided to insure detonation. On top of the container is a ring for lowering the charge into a hole. The cleat placed above and to the side of the cap well is for attaching both electric or nonelectric primers.

b. Uses. Ammonium nitrate is used chiefly as a cratering charge because of its pushing or heaving characteristics. It is thus also effective in ditching and quarrying.

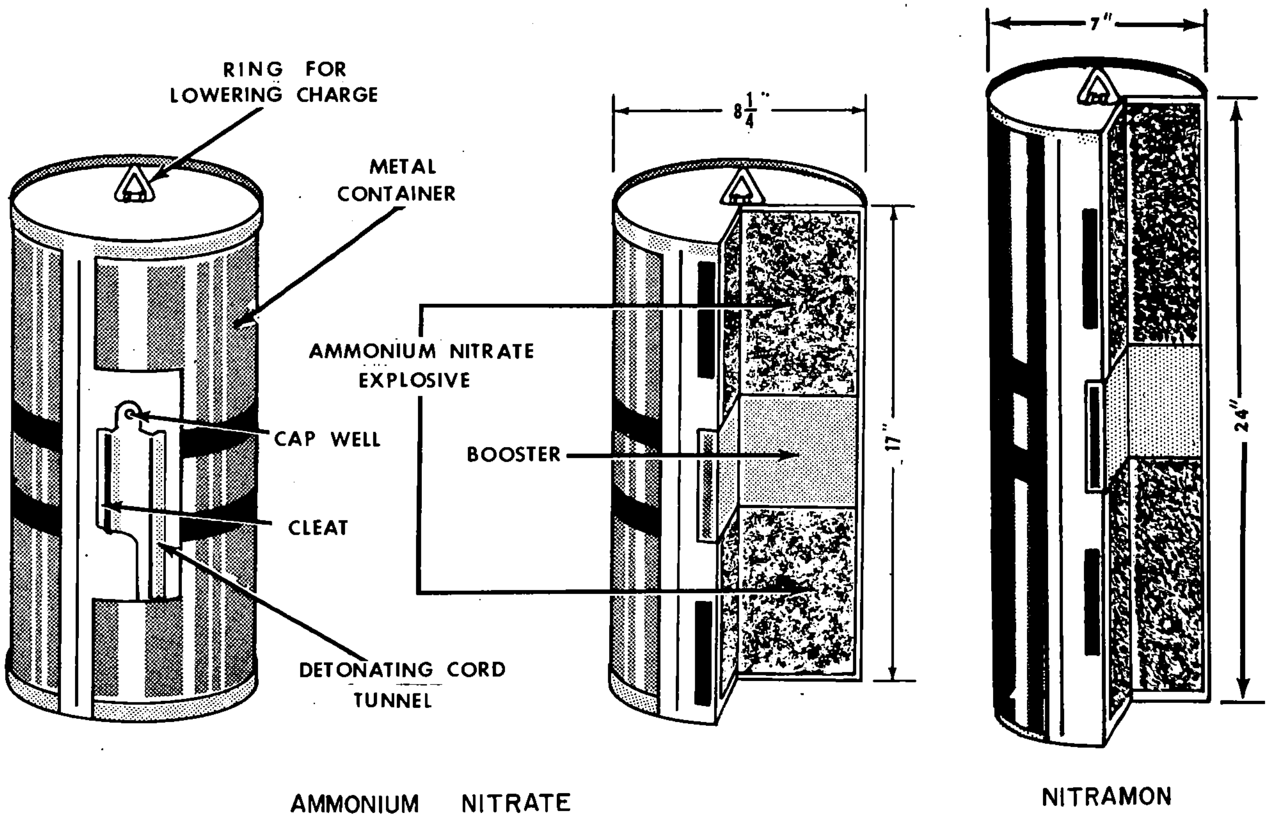


Figure 6. Ammonium nitrate and nitramon cratering charges.

20. Nitramon Cratering Charge

This is a blasting agent comparable with ammonium nitrate. It is not removed from its metal waterproof container for cratering operations because of its hygroscopic characteristics. Generally, the nitramon cratering charge is issued in cylindrical metal containers 7 inches in diameter and 24 inches long. The charge and container weigh 43 pounds. The charge has two priming tunnels. The container has a ring on top for general handling and lowering into boreholes (fig. 6). The nitramon cratering charge, generally used in cratering, is also effective in ditching and quarrying.

21. Shaped Charges

A shaped charge is an explosive charge with its detonating action directed to increase its effectiveness in penetrating steel, armor, and concrete and other masonry (fig. 7). Charges, as issued, are usually cylindrical in shape but may be linear like the charge included in the M157 demolition kit. Cylindrical shaped charges have a conical top, a conical recess in the base, and a conical liner that may be metal, glass, or some other inert material. The threaded cap well in the top is for priming with military electric or nonelectric blasting caps or any standard firing device with blasting cap attached. Shaped charges, generally, are made from such explosives as Composition B, pentolite, and ednatol.

a. M2A3 Shaped Charge. This shaped charge weighs 15 pounds and contains 11½ pounds of pentolite (PETN and TNT) or Composition B (RDX and and TNT). For protection, the explosive is issued in a water-resistant fiber container (fig. 7). A cardboard cylinder, fitted to the charge before use, provides the necessary standoff distance. Three M2A3 shaped charges are packed in a wooden box.

b. M3 Shaped Charge. The M3 shaped charge consists of approximately 30 pounds of 50/50 pentolite, or Composition B, and a 50/50 pentolite booster in a metal container (fig. 7). The shaped charge has a metal cavity liner. A metal tripod provides the correct standoff distance. The M3 shaped charge is packed one each in a wooden box.

c. Effects of Shaped Charges. The effectiveness of shaped charges depends largely on the shape of the cone, the explosive used, and proper placement. They require a special standoff distance from the target, usually provided by a fiber sleeve or metal legs.

d. Special Precautions. In order to achieve the maximum effectiveness of shaped charges—

(1) Center the charge over the target point.

(2) Set the axis of the charge in line with the direction of the hole.

(3) Use the pedestal provided to obtain the proper standoff distance.

(4) Be certain that there is no obstruction in the cavity liner or between the charge and the target.

(5) Be certain that soldiers using shaped charges in the open are at least 900 feet away in defilade under cover, or at least 300 feet away if in a missile-proof shelter, before firing.

22. Bangalore Torpedo

The M1A2 bangalore torpedo consists of loading assemblies, connecting sleeves, and a nose sleeve (fig. 8). Each loading assembly, which may be used singly, is a 5-foot length of steel tubing 2⅛ inches in diameter filled with 8½ pounds of Composition B explosive and weighs 13 pounds. Four inches of length at both ends is filled with a Composition A-3 booster. All sections have a threaded cap well at each end so that they may be assembled in any order. The connecting sleeves make rigid joints. A nose sleeve is placed on the front of the torpedo to assist in pushing it through entanglements and across the ground. It is also desirable to attach an improvised leading section without explosive on the end to forestall premature detonation by a mine when the torpedo is shoved into place. In the assembly of two or more tubes, the nose sleeve is pressed onto one end of one tube, and the other end is connected to a second tube by a connecting sleeve. A bangalore torpedo or torpedo section may be improvised by the use of 2-inch diameter pipe with a 24-gage wall thickness with approximately 2 pounds of explosive per foot of length. Successive pipe lengths, however, must be closely connected.

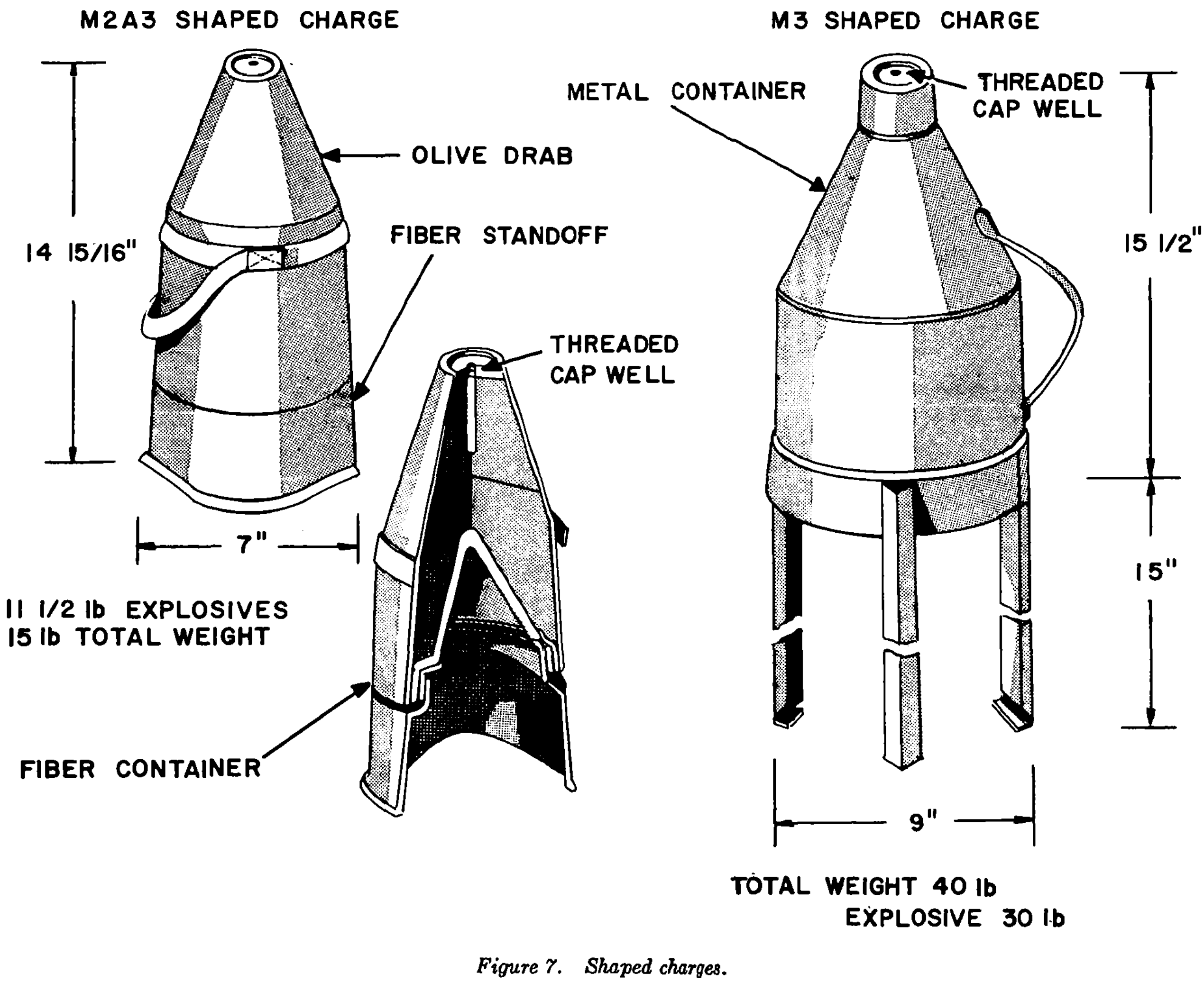


Figure 7. Shaped charges.

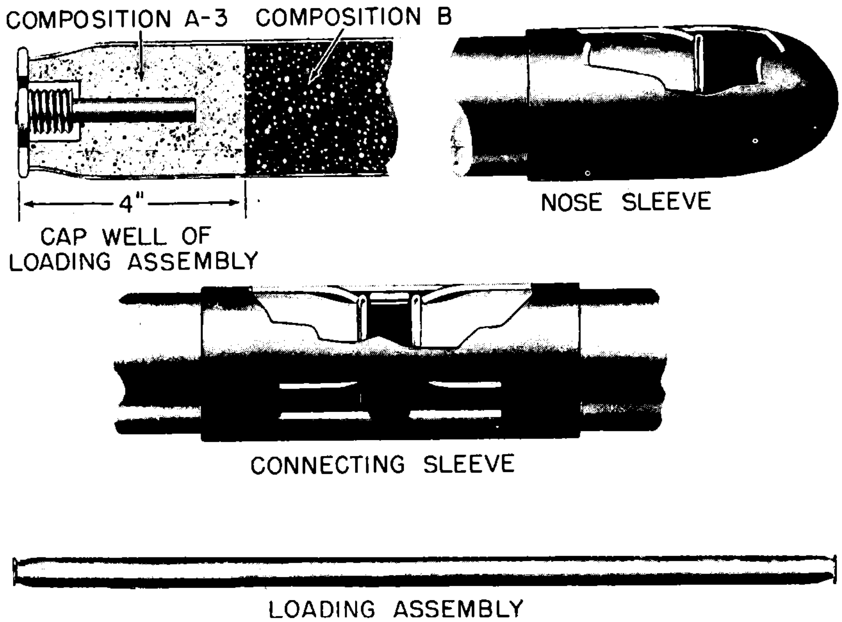


Figure 8. M1A2 bangalore torpedo.

a. Use. The bangalore torpedo clears a path 10 to 15 feet wide through barbed wire entanglements. In minefield breaching, it will explode all antipersonnel mines and most of the antitank mines in a narrow foot path. It should be used for this purpose, however, only in an emergency, as many of the mines at the sides may be shocked into a sensitive state, which makes extreme care necessary in any further mine clearing. Bangalore torpedoes are also useful as expedient individual charges.

b. Detonation. The military electric or nonelectric blasting caps will detonate the bangalore torpedo. In obstacle clearance, the bangalore torpedo should be primed after it has been placed. The cap well at the end should be protected with tape or a wooden plug while the torpedo is being pushed into place. In combat, priming is generally done in three ways—by means of an adapter, a military nonelectric blasting cap, and time fuse; detonating cord with a clove hitch and two extra turns around the Composition A–3 portion of the torpedo (fig. 8); or a pull type firing device with a nonelectric blasting cap crimped on.

23. Rocket-Propelled Train Bangalore Torpedo (Barney Google)

The train consists of 20 sections of bangalore torpedo fitted together by special connecting sleeves to form a 100-foot train (fig. 9). A kit contains the rocket motor, tail assemblies, and couplings for 20 sections. The motor is fitted to the front of the train to provide propulsion. Detonation occurs at the tail assembly by means of a pull fuze, a nonelectric blasting cap, and a reel of cable.

a. Uses. The rocket-propelled bangalore torpedo is used against barbed wire entanglements, antipersonnel mines, and similar small obstacles. The rocket propulsion enables deeper penetration of small obstacles with less chance of exposure of soldiers to enemy observation and fire.

b. Detonation. The assembled torpedo is placed at a spot within range of the target. The 400-foot reel of cable is shortened to the proper length and its free end is anchored firmly. After the safety has been unscrewed from the tail assembly and all soldiers have taken cover, the rocket motor is fired electrically. After the torpedo has traveled a distance equal to the length of the anchored cable, the pull fuze is actuated and the assembly is detonated.

24. Projected Charge Demolition Kits

a. M3 and M3A1 Kits. These are approximately 14 inches wide, 5 inches high, and 400 feet (121.9 meters) long, weighing approximately 9,000 pounds, including 4,500 pounds of explosive. These kits are supplied in eliptically-shaped units or elements 5 feet long, containing 70 pounds of explosive. The M3 consists of an 80/20 amatol charge and a 6-inch crystalline TNT booster at each end. The M3A1 consists of Composition B charge and a Composition A–3 booster. Both types have a threaded cap well suitable for a standard firing device and an electric or nonelectric military blasting cap. This cap well also makes possible the use of the explosive element as a separate charge. Bangalore torpedo explosive elements may be substituted for the standard explosive elements, four for each.

b. M–157. This kit measures about 12 inches in width, 7 inches in height, and 400 feet (121.9 meters) in length. It weighs 11,000 pounds including 3,270 pounds of explosive. The explosive is a linear shaped charge, 12 inches wide, 7 inches high, and 5 feet long, containing approximately 45 pounds of Composition B and 2.5 pounds of Composition C–4. As the insert tubes are welded to the walls of the center loading sections, the explosive elements cannot be used as separate charges or replaced by any substitute item in the field. The linear shaped charge insures a wider clear path through minefields (TM 9–1375) than many other explosive clearing devices.

c. Use. Projected demolition charges are used chiefly in the deliberate breaching of minefields. They are also effective against bands of log posts, steel rail posts, antitank ditches, and small concrete obstacles. These charges are adequate to break down the sides of an antitank ditch. They will also clear a path adequate for tank traffic, if the ditch is unrevetted and 5 feet deep or less and if the charges project beyond the far side of the ditch. Generally, it is impractical to breach ditches deeper than 8 feet. The explosive elements of the M3 and M3A1 projected charges may be used as expedient individual charges.

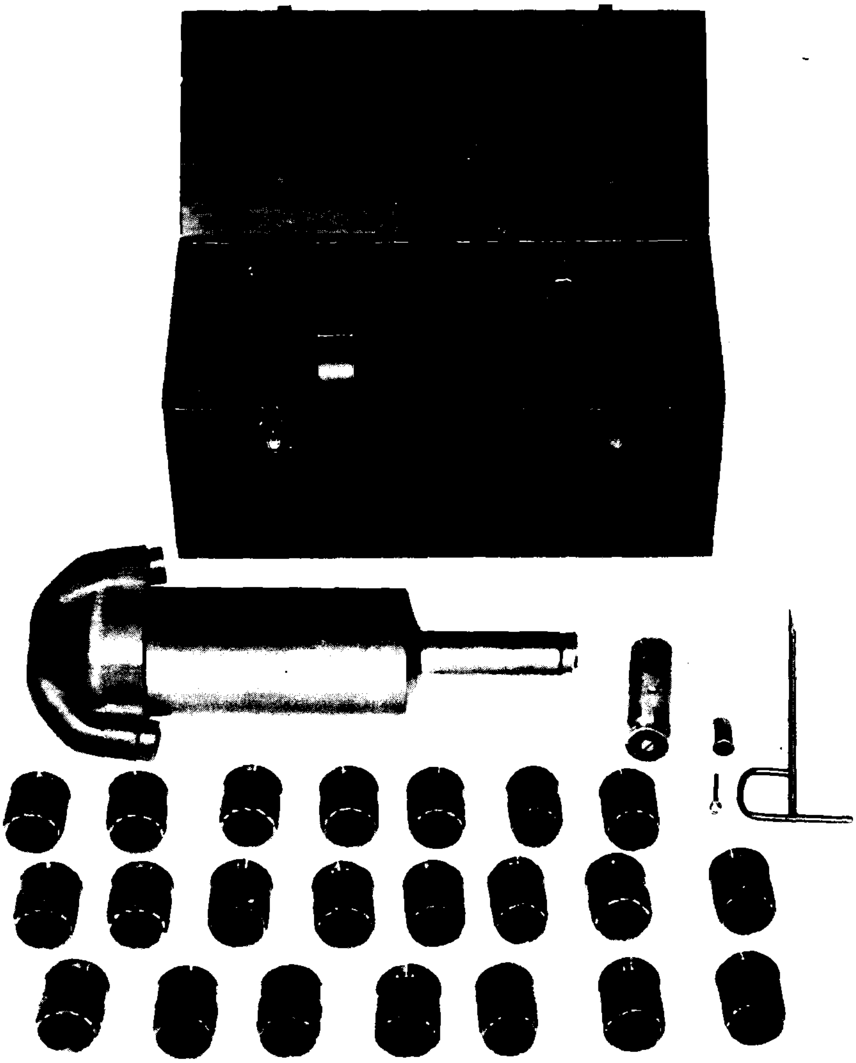


Figure 9. Rocket-propelled train bangalore torpedo.

d. Detonation. The charges are generally detonated from a tank by means of the bullet impact fuze, which has a target plate that bears on the firing pin and is held in place by a shear pin and a safety fork that must be removed before the fuze can be actuated. Two fuzes are provided to insure that one is visible to the tank gunner at all times. Models M3 and M3A1 may also be detonated by fire from the main tank armament or any 37 mm or larger high explosive shell with a superquick fuze.

25. Projected Charge Demolition Kit, M1

This projected flexible linear charge is designed to clear a path through antipersonnel minefields. Its components are a nylon-covered detonating cable, launcher, fuse lighter, delay detonator, anchor stake, and carrying case. The explosive item, or detonating cable, is 1 inch in diameter and approximately 170 feet (51 meters) long; it weighs 63 pounds, 46 pounds of which is oil-soaked PETN. The detonating cable is composed of 19 strands of special detonating cord, each containing 100 grains of PETN per foot. This differs from the regular (reinforced) detonating cord, which contains only 50 grains of PETN per foot. Regular detonating cord cannot be used as a substitute in the kit.

a. Use. This kit, emplaced to project the cable across a pressure-actuated antipersonnel minefield, clears a path 1 foot wide and exposes most mines in a 3-foot path by the removal of the soil above them. These mines having become extremely sensitive, must be handled or disarmed only by highly trained soldiers.

b. Detonation. One soldier fires the complete assembly. First the kit is emplaced; then the fuze lighter on the jet propulsion unit is pulled. The 15-second delay in the propulsion fuse allows the soldier to move the 5-foot distance from the launcher to the anchor stake and pull the fuse lighter safety pin and firing ring on the detonating cable, (which also has a 15-second delay) and then take cover at least 100 feet behind the assembly.

26. M37 Demolition Charge Assembly

The M37 charge assembly consists of eight M5A1 demolition blocks (Composition C4, par. 11), eight demolition block hook assemblies, and two M15 priming assemblies. The demolition blocks are packed in two bags, four blocks per bag and placed in an M85 carrying case. Two of these carrying cases are packed in a wooden box. The M15 priming assembly is a 5-foot length of detonating cord with two plastic adapters and two RDX boosters attached. The adapters are threaded to fit the standard cap well in the demolition block. The priming assembly has two detonating cord clips for fixing the M37 charge assembly to the main line.

a. Use. This assembly is applicable to the use of assault demolition teams in the reduction of small obstacles. It is very effective against small dragon's teeth approximately 3 feet high and 3 feet wide at the base.

b. Detonation. The M37 demolition charge is detonated by means of the M15 priming assembly and an electric or nonelectric blasting cap or by a ring main attached by means of the detonating cord clips provided.

27. Improvised Charges

Demolition teams operating in the field frequently find targets to which standard methods and charges may not apply and improvisations are required. Frequently the success of the mission depends upon the ingenuity of the team. The package and pole charges are such improvisations. By skillful modifications, they may be applied successfully in many situations.

a. Package Charges. Charges prepared in convenient packages of appropriate size and shape are always more readily put in place than other types. Explosives may be packaged in sandbags to make elongated cylindrical charges for boreholes. Blocks of TNT or other explosives may be stacked together and bound with tape or twine or wrapped in canvas cloth, or paper. A satchel charge may be improvised by tying or taping explosive blocks to a board with a handle attached. Large charges may consist of an entire case of explosives. Here one block or one cartridge is removed from the case, primed, and replaced. A larger charge may be made by lashing several cases of explosive together. The detonation of a single primer will fire the entire charge. Dual priming systems, however, should be used, if practical.

b. Pole Charges. Pole charges are convenient for placement against pill boxes, hard-to-reach bridge stringers, underwater bridge supports, and other locations not easily accessible. Pole charges are usually an assembly of an explosive charge, detonating cord, fuze lighter, time fuse, nonelectric blasting cap, and a pole for placing or propping them in position. Pole charges are usually prepared in the same manner as package charges. Dual priming should be used, if possible.

CHAPTER 2

FIRING SYSTEMS AND EQUIPMENT

Section I. NONELECTRIC FIRING SYSTEM

28. Introduction

Three types of systems for firing demolitions explosive charges are available—nonelectric, electric, and detonating cord. All three have individual priming methods and materials. The nonelectric system, with which this section is primarily concerned, and the electric system may also be used in a detonating cord system. All three may be used simultaneously or interchangeably in a dual firing system.

29. System Components and Assembly for Detonation

Nonelectric priming is the preparation of an explosive charge for nonelectric detonation. The priming materials consist mainly of a blasting cap, which provides the shock adequate to initiate the explosive, and the fuse, which transmits the flame that fires the blasting cap. The assembly of the nonelectric system and a description of the components follow.

a. Capping the Fuse.

(1) *Method.*

(*a*) Cut and discard a 6-inch length from the free end of the fuse (fig. 10). Do this to be sure that there is no chance of misfire from a damp powder train because of the absorption of moisture from the open air. Then cut off a measured length of fuse to check the burning rate.

(*b*) Cut the fuse long enough to permit the soldiers detonating the charge to reach a safe distance before the explosion. This cut should be made squarely across the fuse (fig. 10).

(*c*) Take one blasting cap (fig. 11) from the cap box, hold it with the open end down, and shake it gently to remove any dirt or foreign matter. *Never tap the cap with a hard object or against a hard object. Never blow into the cap.*

(*d*) Hold the fuse vertically with the cut end up and *slip the blasting cap gently down over it so that the explosive in the cap is in contact with the end of the fuse; if not, it will be a misfire. Never force the fuse into the blasting cap.* If the end is flattened or it is too large to enter the blasting cap freely, roll the fuse between the thumb and fingers until the size is reduced to permit its free entry into the cap.

(*e*) After the blasting cap has been seated on the fuse, grasp the fuse between the thumb and third finger of the left hand and extend the forefinger over the end of the cap to hold it firmly against the end of the fuse. Keep a slight pressure on the closed end of the cap with the forefinger.

(*f*) Slide the second finger down the outer edge of the blasting cap to guide the crimpers (fig. 12) and thus obtain accurate crimping, even in darkness.

(*g*) Crimp the blasting cap at a point 1/8 to 1/4 of an inch from the open end. *A crimp too near the explosive in the blasting cap may cause detonation. Point the cap out and away from the body during crimping.*

(*h*) If the blasting cap should remain in place several days before firing, protect the joint between the cap and the fuse with a coating of sealing compound or some similar substance. As this sealing compound, a standard issue, does not make a waterproof seal, submerged charges should be fired immediately.

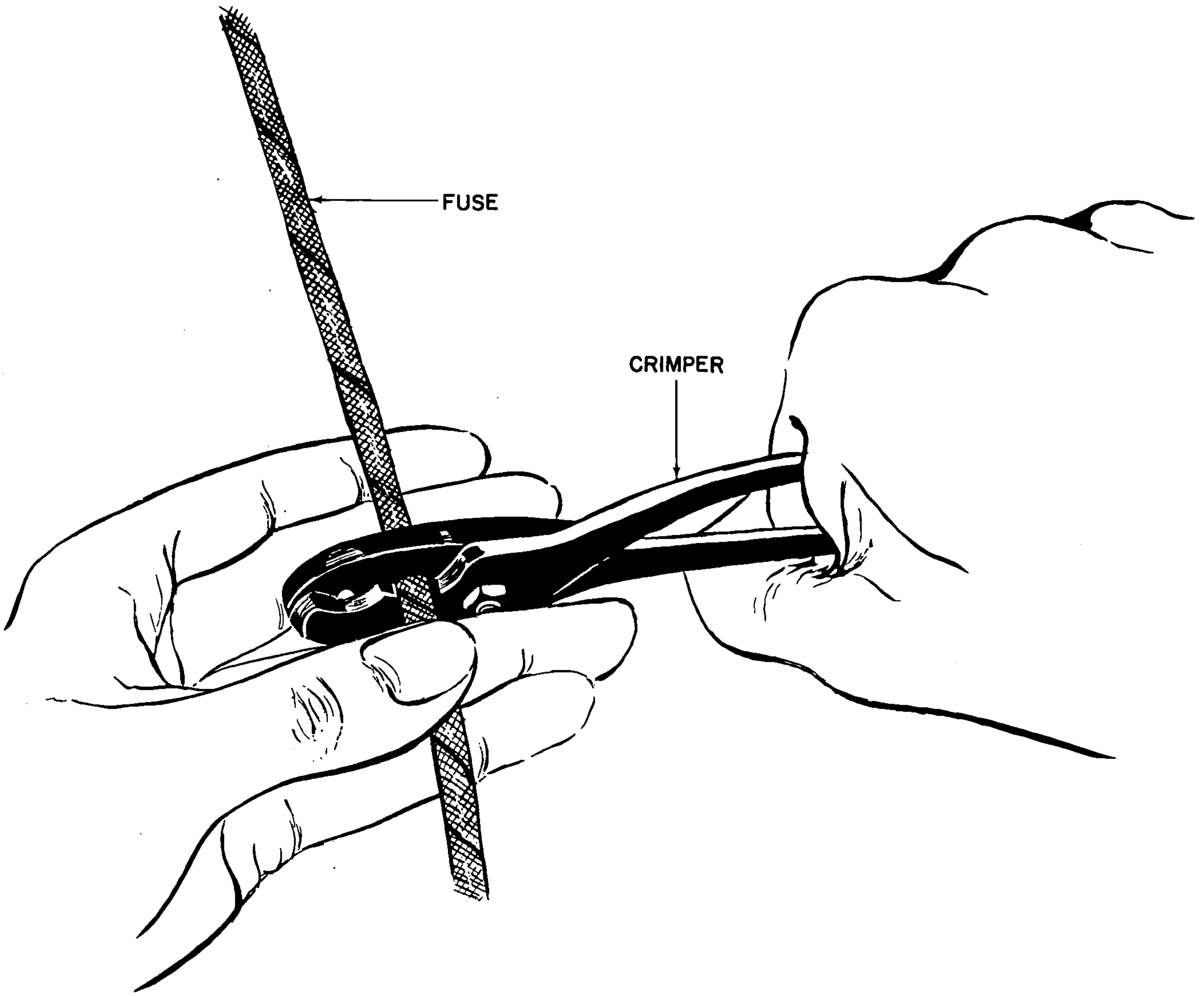
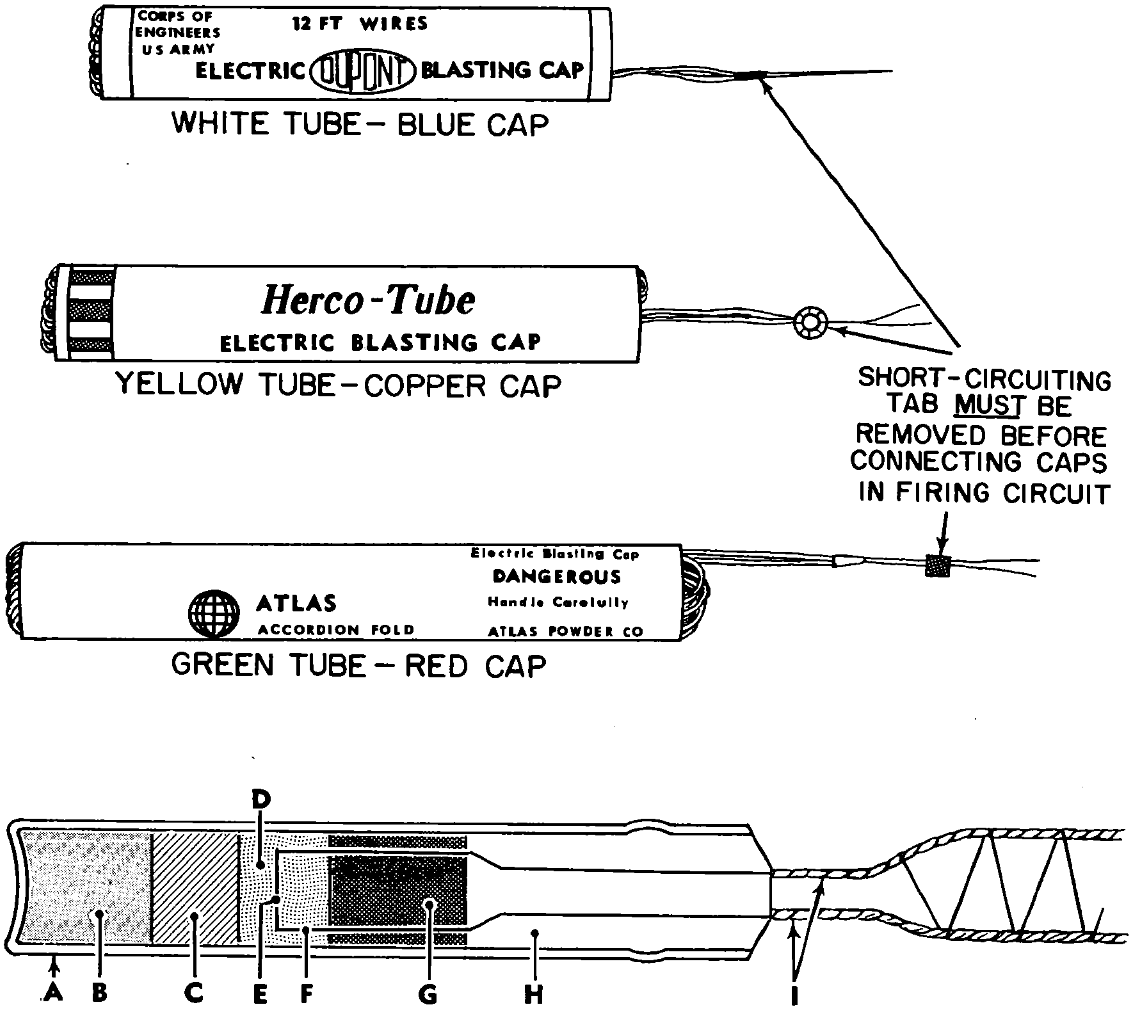
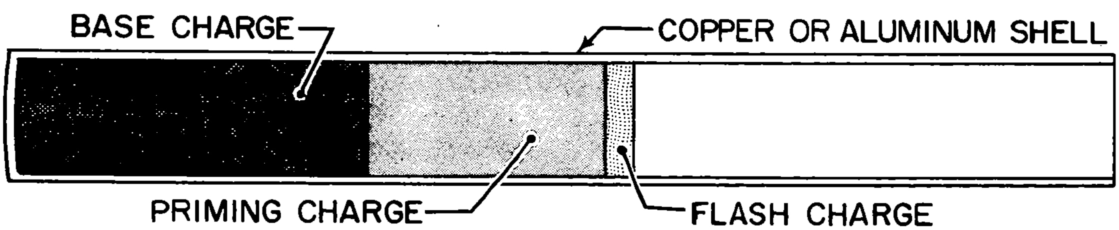


Figure 10. Cutting the fuse.



A METAL SHELL
B DETONATING CHARGE
C INTERMEDIATE CHARGE
D IGNITING CHARGE
E PLATINUM WIRE OR BRIDGE HEATED BY THE ELECTRIC CURRENT
F ENDS OF LEAD WIRES SET IN IGNITING CHARGE
G PLUG (ASPHALT)
H FILLING MATERIAL
I INSULATED LEAD WIRES

1 CAP, BLASTING, TETRYL, ELECTRIC EXTERIORS AND CROSS SECTION



2 CAP, BLASTING, NONELECTRIC

Figure 11. Electric and nonelectric blasting caps.

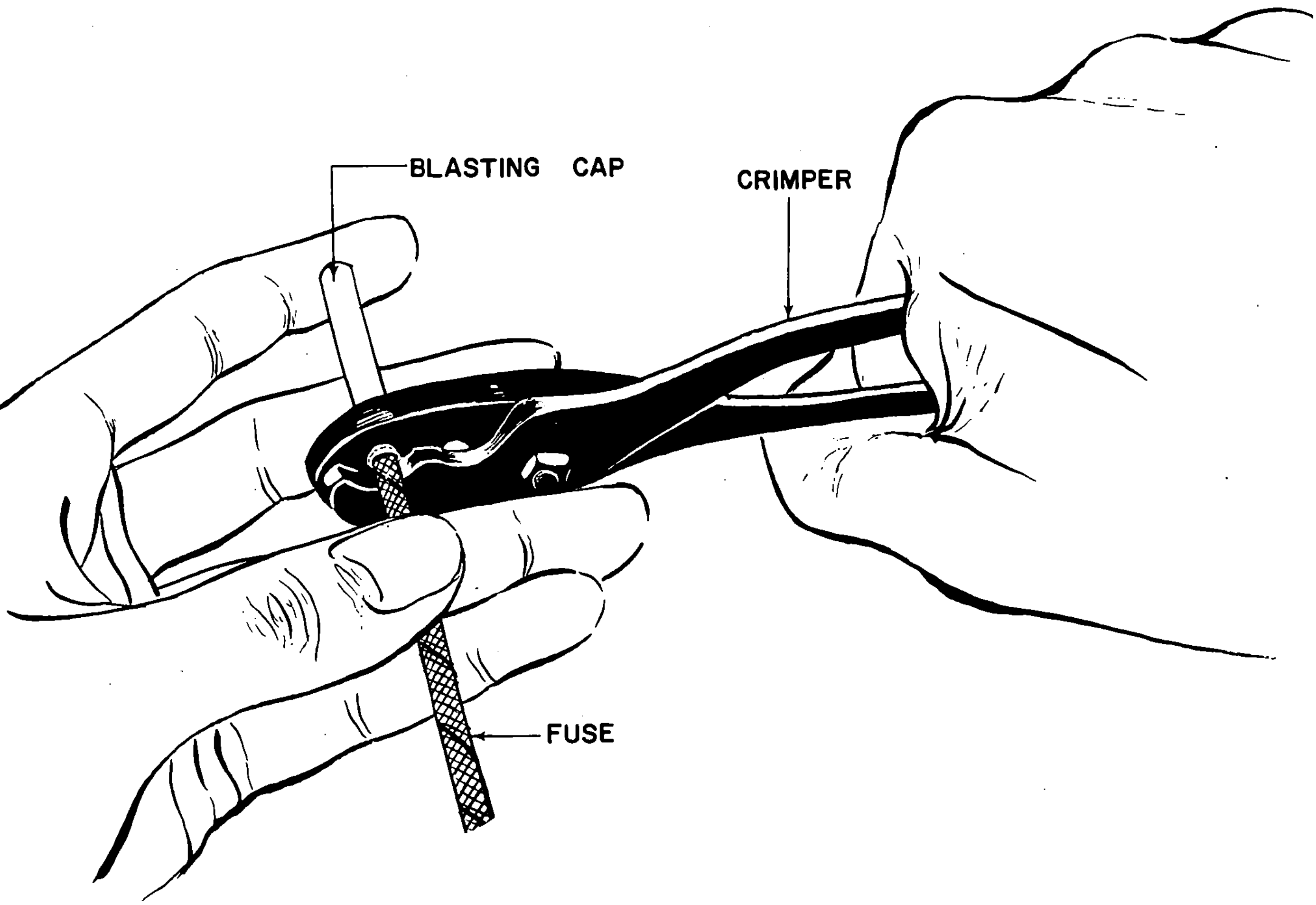


Figure 12. Crimping cap on fuse.

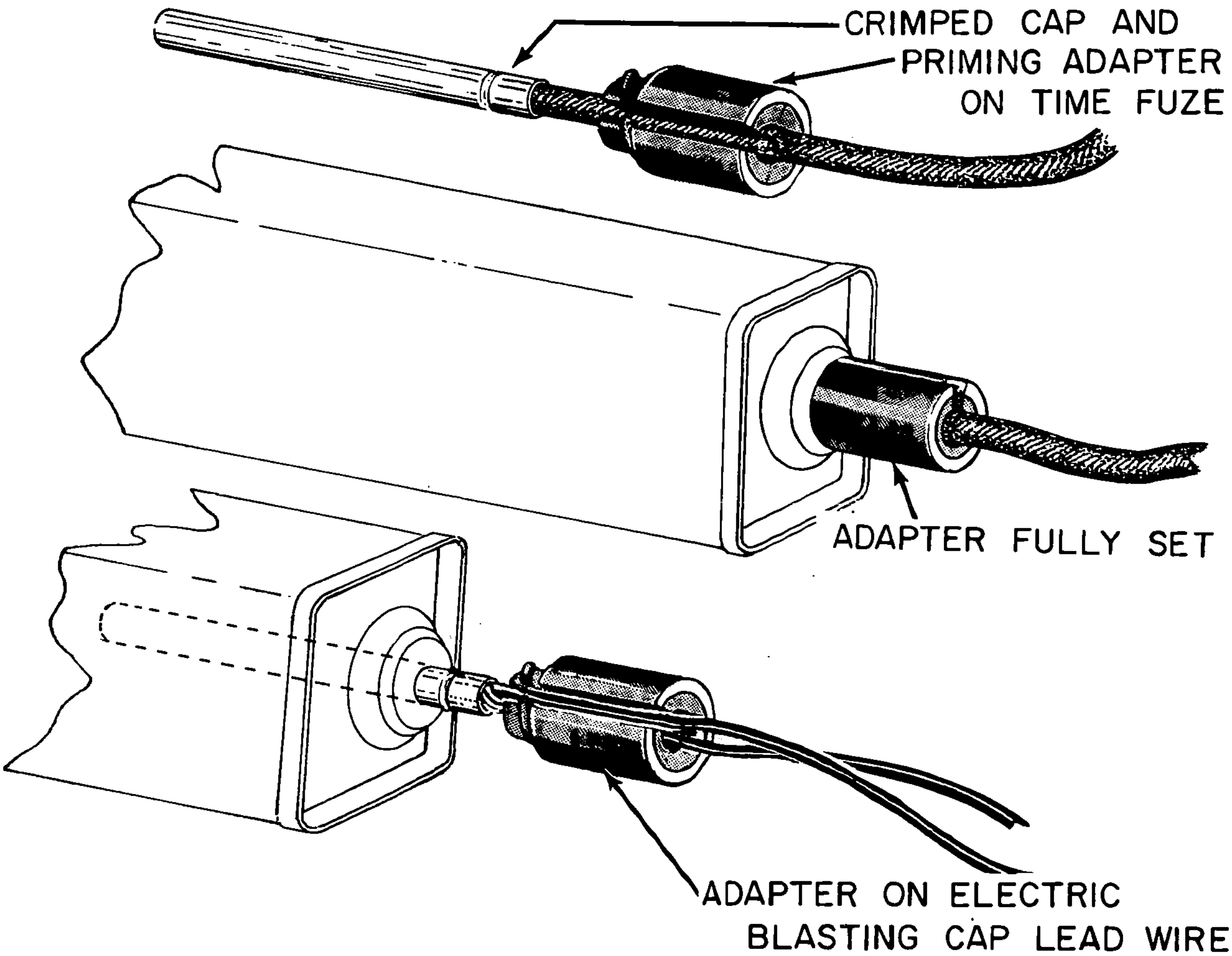


Figure 13. Priming adapter.

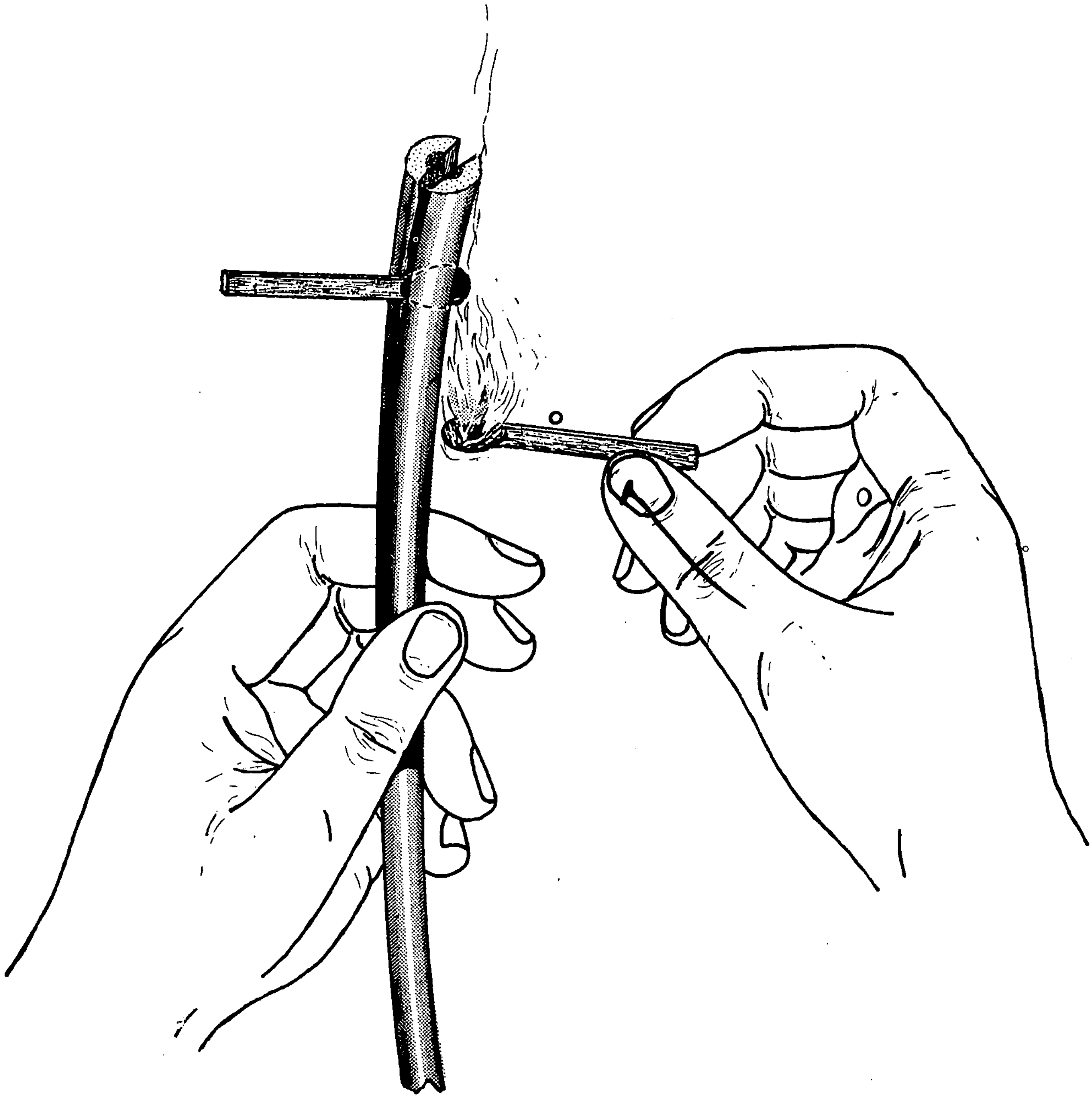


Figure 14. Lighting time fuse with match.

(2) *Capping with and without priming adapter.*

(*a*) *With priming adapter.* Pass the end of the fuse through the adapter and (fig. 13) crimp on the nonelectric blasting cap. Then pull the cap into the adapter and insert into the cap well of the explosive. Now screw the adapter into place.

(*b*) *Without priming adapter.* If no priming adapter is available, insert the capped fuse into the cap well and tie it in place by means of a string or fasten it by means of adhesive tape or some other available material.

b. Lighting the Fuse. Time fuse or safety fuse M700 may be ignited with a match or a fuse ligher.

(1) *With match.* Split the time fuse at the end (fig. 14) and place the head of an unlighted match in the powder train. then light the inserted match head with a flaming match.

(2) *With M2 weatherproof lighter.* This device was designed as a positive method of lighting time fuse and safety fuse M700 (fig. 15). It operates effectively under all weather conditions—even underwater if it is properly waterproofed. A pull on the striker retaining-pin causes the striker to hit the percussion cap, igniting the fuse. A sealing compound is generally used to waterproof the joint between the fuse and the lighter. Although the plastic sealing compound is applied and the nonelectric firing assembly is properly prepared, any slight disturbance of the lighter on the time fuse allows water to enter at the union when installed underwater. The attachment and operation of the M2 weatherproof fuse lighter are as follows:

(*a*) Slide the pronged fuse retainer over the end of the fuse and firmly seat it.

(*b*) Waterproof the joint between the fuse and the lighter, if necessary, by applying sealing compound.

(*c*) In firing, hold the barrel in one hand and pull on the release pin with the other.

(3) *With M60 weatherproof fuse lighter.* This device is designed to ignite time fuse and M700 safety fuse in all sorts of weather conditions and underwater. The fuse is inserted into a fuse retainer and sealed and waterproofed by means of two rubber seals (fig. 16). A pull on the pull ring releases the striker assembly, allowing the firing pin to drive against the primer, which ignites and initiates the fuse. The lighter is operated as follows:

(*a*) Unscrew the fuse holder cap two or three turns.

(*b*) Press the shipping plug into the lighter to release the split collet, and rotate the plug as it is removed.

(*c*) Insert a freshly cut end of time fuse in the place of the plug, until it rests against the primer.

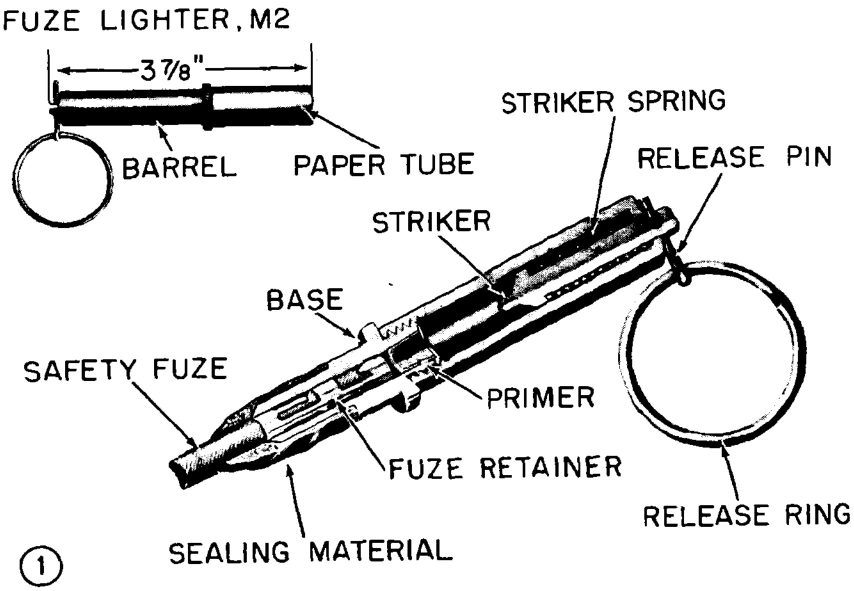


Figure 15. M2 fuse lighter.

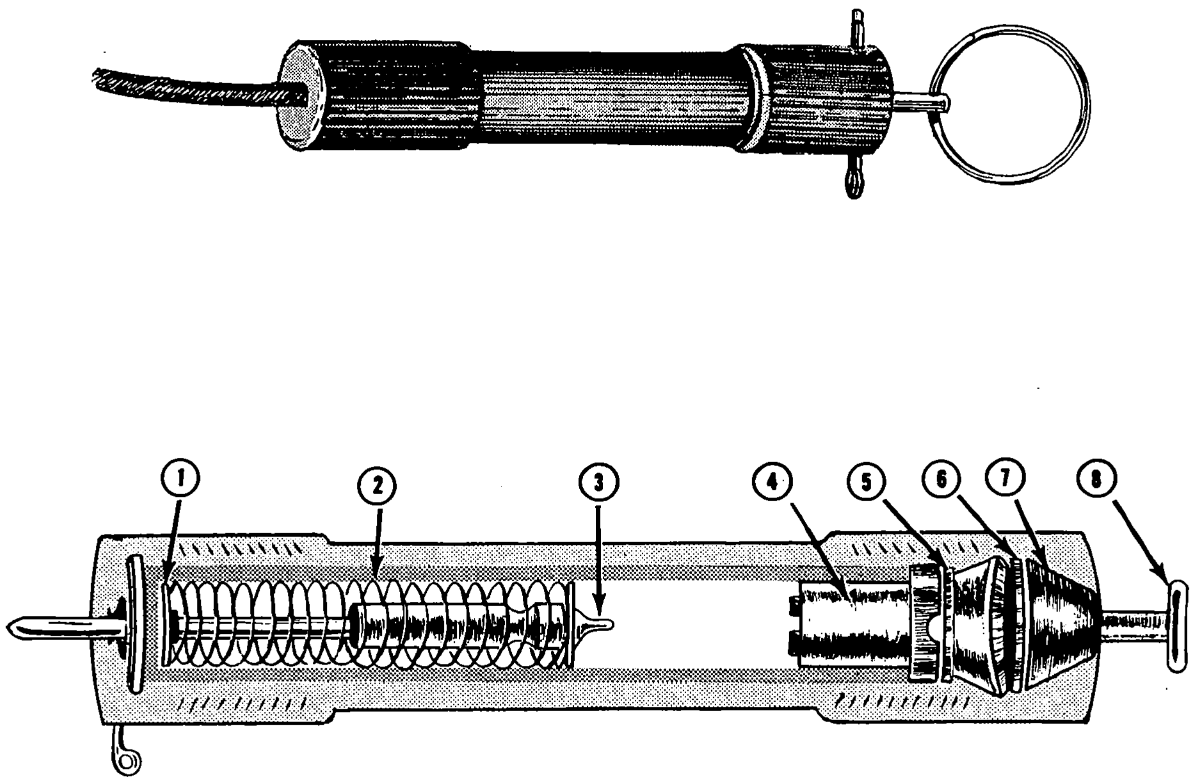


Figure 16. M60 fuse lighter.

(*d*) Tighten the cap sufficiently to hold the fuse tightly in place and thus waterproof the joint.

(*e*) To fire, remove the safety pin, hold the barrel in one hand, and pull on the pull ring with the other. In the event of a suspected misfire, the M60 can be reset quickly without disassembly by pushing the plunger all the way in and attempting to fire as before; it cannot be reset underwater, however, because water can enter the interior of the nylon case through the holes in the pull rod. The fuse lighter is reusable after the reassembly of the parts and the insertion of a new primer.

c. Description of Components and Accessories Used.

(1) *Blasting caps.* Two types of blasting caps are used—military and commercial. The military type has a thin noncorrosive metallic shell about 2½ inches long and ¼ inch in diameter that contains an initiating explosive and a charge. Details of a typical nonelectric blasting cap are shown in figure 11. Because nonelectric blasting caps are extremely difficult to waterproof, they should not be used in underwater charges or charges in wet boreholes; but if such be necessary, they should be covered with a water proofing compound and fired immediately after placement. Nonelectric blasting caps available are the military type 1 (J 1 PETN), RDX, or PETN (M–7), and tetryl and the commercial typc No. 8. The military cap will detonate military explosives, and the commercial cap, sensitive explosives, such as tetryl, detonating cord, and nitrostarch.

(2) *Cap crimper.* The M2 cap crimper (fig. 12) is used to squeeze the shell of a nonelectric blasting cap around a time fuse, a standard base, or detonating cord securely enough to keep it from being pulled off but not tightly enough to interfere with the burning of the powder train in the fuse or the detonation of the detonating cord. The M2 crimper forms a water resistant groove completely around the blasting cap. The rear portion of the jaws is shaped and sharpened for cutting fuse and detonating cord. One leg of the handle is pointed for use in punching holes in explosive materials for the easy insertion of blasting caps. The other leg has a screwdriver end. Cap crimpers, being made of a soft nonsparking metal, must not be used as pliers for any purpose, as this damages the crimping surface. Also the cutting jaws must be kept clean and be used only for cutting fuse and detonating cord. The cap is crimped to thc fuse as shown in figure 12.

(3) *Fuses.* Two types of fuse are used to set off the blasting cap-time fuse and M700 safety fuse. These may be used interchangeably.

(*a*) *Blasting time fuse.* This consists of black powder tightly wrapped with several layers of fabric and waterproofing materials. It may be any color, orange being the most common (fig. 17). This fuse burns slowly at a uniform rate, allowing the soldier firing the charge to reach safety before the cxplosion. As the burning rate may vary between rolls from 30 seconds or less to 45 seconds or more per foot, each roll must be tested prior to using under actual conditions in the area where the charge is to be placed (*a*(1) above).

(*b*) *Safety fuse M700.* This fuse (fig. 18) is similar to a time fuse and may be used interchangeably with it. The fuse is a dark green cord 0.20 inches in diameter with a plastic cover, either smooth or with single painted abrasive bands around the outside at 1-foot or 18-inch intervals and doublc paintcd abrasive bands at 5-foot or 90-inch intervals depending on the time of manufacture. These bands are provided for easy measuring purposes. The powder burns at a uniform rate of approximately 40 seconds per foot, which permits the soldicr firing the charge to reach a place of safety. The burning rate, however, must always be tested in the same manner as that of a time fuse (*a*(1) above).

(*c*) *Packaging.* Time fuse and safety fuse M700 are issued in 50-foot rolls; two rolls, one nested inside the other, are packed together. One can contains 500 feet of fuse.

(*d*) *Storage and handling.* Time fuse and safety fuse M700 should be stored in a

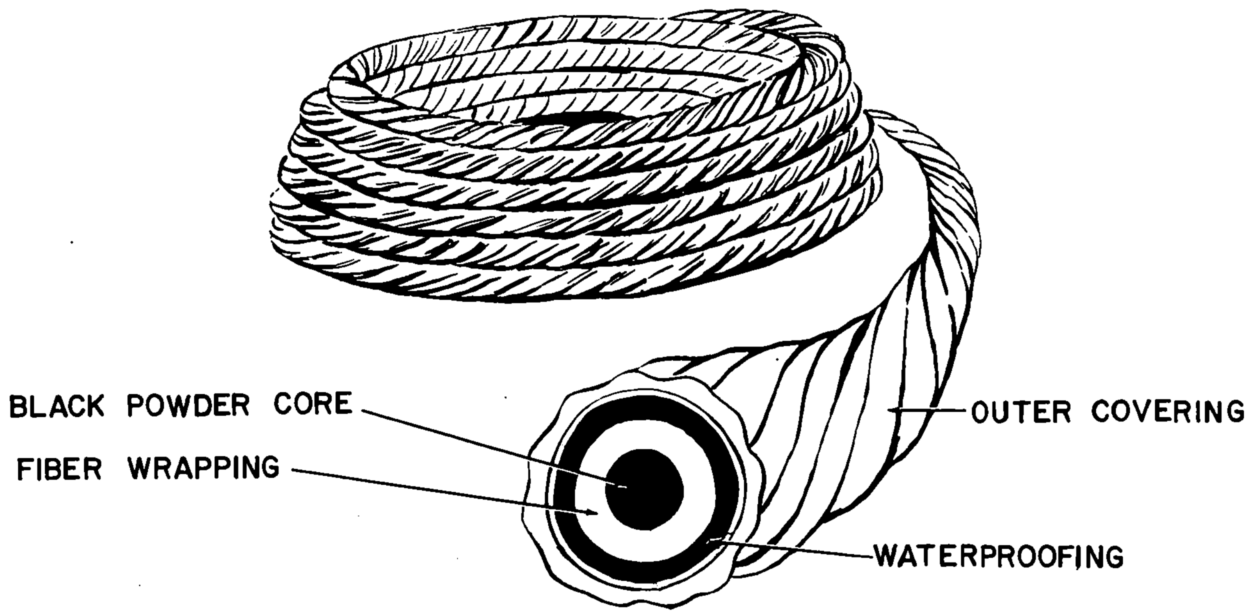


Figure 17. Blasting time fuse.

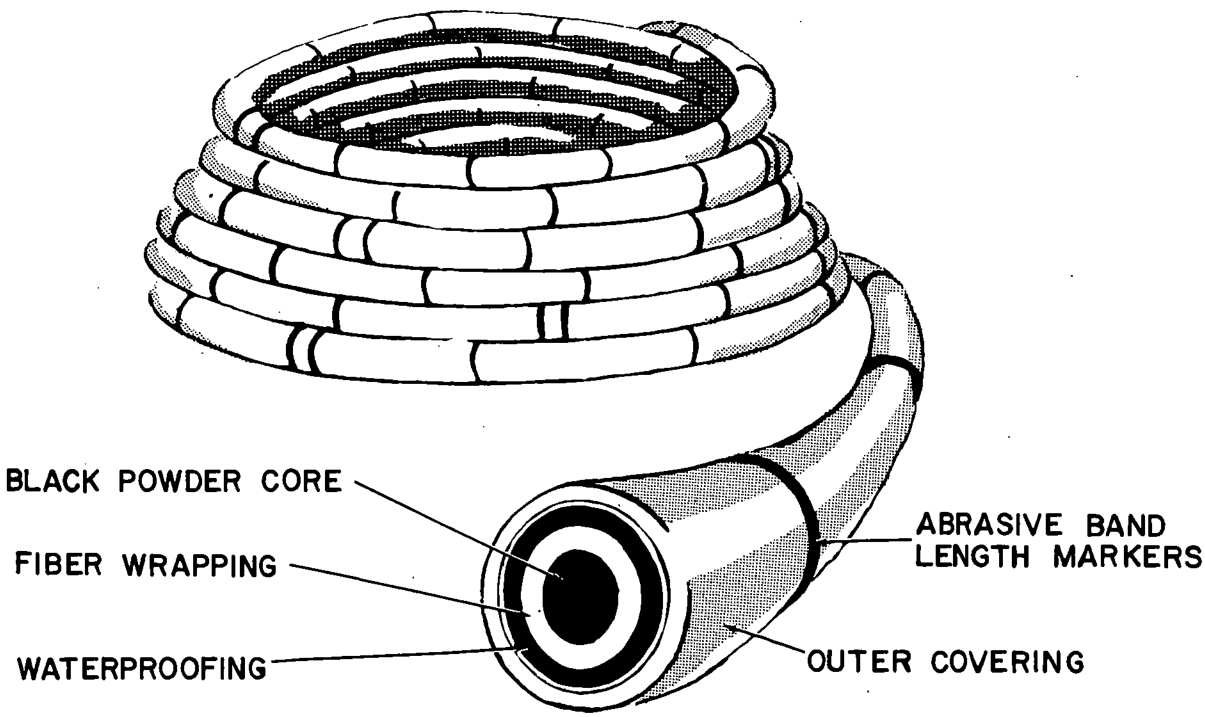


Figure 18. Safety fuse M700.

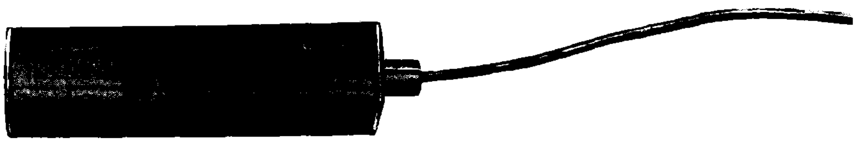


Figure 19. One-pound block of TNT primed nonelectrically.

cool, dry place, free from oils, paints, gasoline, kerosene, and similar distillates and solvents. Twists, kinks, or sharp bends that may crack the covering or cause breaks in the powder train must be avoided.

30. Nonelectric Priming of TNT and M2 Demolition Block

a. With Priming Adapter. Priming adapters simplify the priming of military explosives with threaded cap wells (fig. 13). The shoulder inside one end of the adapter is large enough to admit time fuse or detonating cord, but too small for a blasting cap. The other end of the adapter fits the internal thread of threaded cap wells in military explosives. TNT and M2 demolition blocks with threaded cap wells are primed nonelectrically by the use of a priming adapter (figs. 13, 19, and par. 29*a*(1), (2)).

b. When Priming Adapter Is Not Available. When the priming adapter is not available or the explosive blocks have no threaded cap wells, they are primed as follows:

(1) *Method 1.*

(*a*) Wrap a string tightly around a block and tie it securely leaving about 6 inches of loose string on each end after making the tie.

(*b*) Insert a blasting cap with fuse attached into the cap well.

(*c*) Tie the loose string around the fuse to protect the blasting cap from being separated from the block.

(2) *Method 2.* Insert fused cap into cap well, grasp fuse with thumb and forefinger at top of cap well, and remove fused cap from the block of explosive. Then by using string approximately 40 inches in length, tie two half hitches around fuse so the tie will be at the tip of cap well when reinserted. Now insert fused cap into well. Wrap long end of string around the block of explosive a minimum of three times along the long axis, each time changing the direction of tie with a half turn around the time fuse, keeping the string taut. Tie off around the time fuse at top of cap well with two half hitches.

31. Nonelectric Priming of M1 Chain Demolition Block

The M1 chain demolition block is primed nonelectrically by fastening a nonelectric blasting cap to one of the free ends of the detonating cord chain. *The explosive end of the cap should point toward the chain demolition blocks.* The firing of the blasting cap detonates the cord, which in turn detonates the entire chain.

32. Nonelectric Priming of Plastic Explosives (Composition C3 and C4)

Nonelectric priming of Composition C3 and C4 consists merely of molding the explosive around a fused blasting cap (1, fig. 20). The explosive must be at least 1 inch thick at the ends of the blasting cap and ½ inch thick on the sides to insure detonation (2, fig. 20). Plastic explosives may also be primed by forming a cap well in the block by means of the pointed end of the crimpers and by the use priming adapters, the same as with TNT. Never try to force a cap into an expedient fuse well that is too small to admit it easily. Never warm plastic explosive over an open flame or expose it to extreme heat.

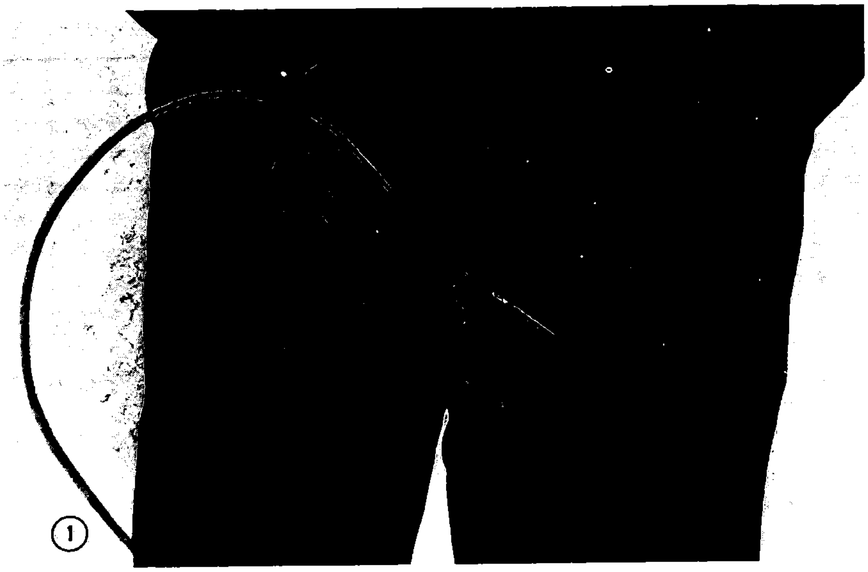
33. Nonelectric Priming of Dynamite

Dynamite cartridges may be primed nonelectrically at one end or at the side. End priming is used either when a whole case is fired or when placed charges require no tamping.

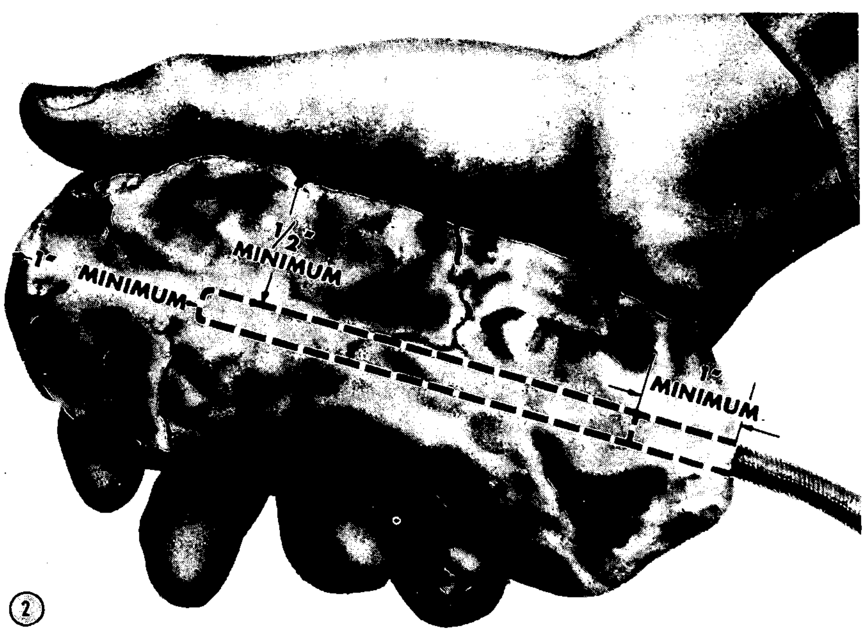
a. End Priming Method.

(1) Punch a hole in the end of the cartridge (1, fig. 21).

(2) Insert a fused blasting cap.

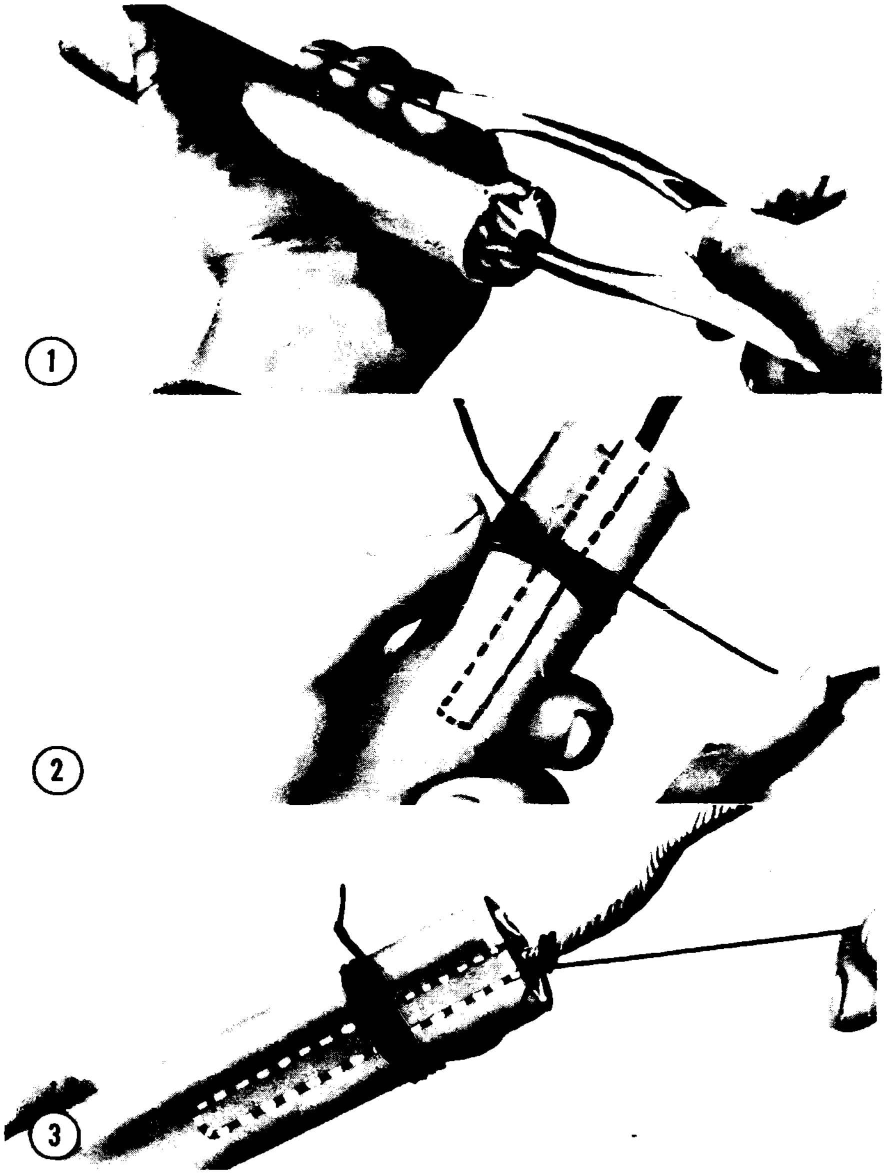


1 Placing blasting cap



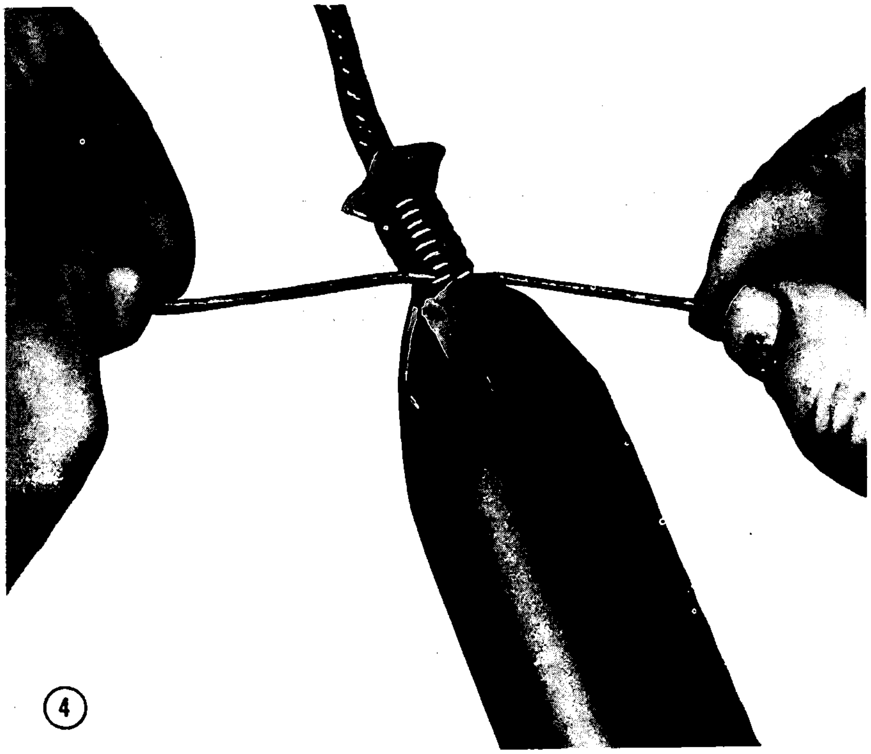
2 Blasting cap in place

Figure 20. Nonelectric priming of plastic explosive.



1 Making cavity with M2 cap crimper
2 Placing and tying cap
3 Tying fuse

Figure 21. Dynamite primed nonelectrically with cap in end.



4 Alternate end priming method

Figure 21—Continued.

(3) Tie the cap and fuse securely in the cartridge (2, 3, fig. 21).

b. Alternate End Priming Method.

(1) Unfold the wrapping at one end of the cartridge.

(2) Roll the end of the cartridge in the hands to loosen the dynamite.

(3) Punch a hole in the exposed dynamite.

(4) Insert a fused blasting cap into the hole.

(5) Close the wrapping.

(6) Fasten the cap and fuse securely with a string or length of tape (4, fig. 21).

c. Side Priming Method.

(1) Punch a hole in the cartridge about 1½ inches from one end (1, fig. 22).

(2) Point the hole so that the blasting cap when inserted, will be nearly parallel with the side of the cartridge and the explosive end of the cap will be at a point at about half the length of the cartridge.

(3) Insert a fused blasting cap into the hole.

(4) Wrap a string tightly around the fuse and then around the cartridge, making two or three light turns before tying the string (2, fig. 22).

(5) Moistureproof the primer by wrapping a string closely around the cartridge, extending it an inch on each side of the hole to cover it completely. Then cover the string with a water-repellent substance (3, fig. 22).

34. Nonelectric Priming of Ammonium Nitrate and Nitramon Cratering Charge

The 40-pound ammonium nitrate and nitramon charges are primed nonelectrically, as follows:

a. Place a fused blasting cap in the cap well on the side of the container (1, fig. 23).

b. Tie a string around the fuse and then around the cleat above the blasting cap (2, fig. 23).

35. Nonelectric Misfires

a. Prevention. Working on or near a misfire is the most hazardous of all blasting operations. A misfire should be extremely rare if these procedures are followed closely—

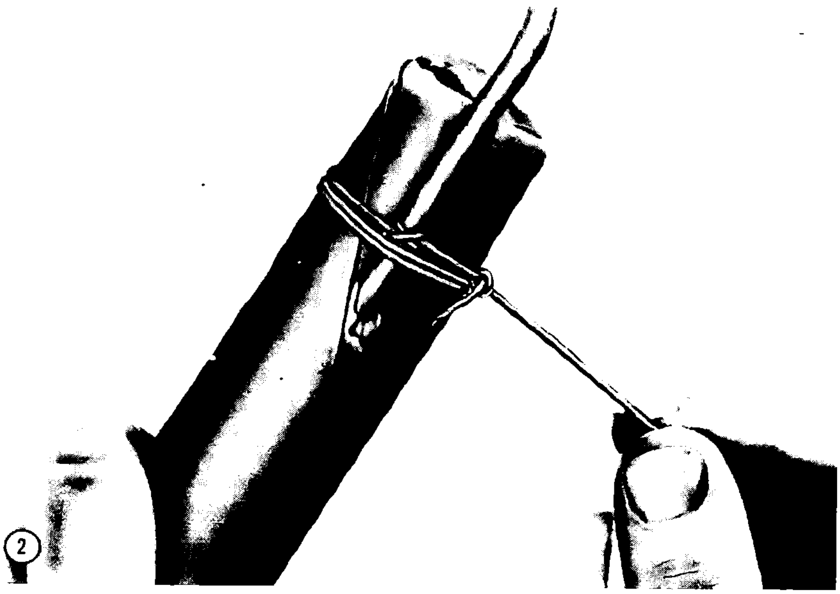
(1) Prepare all primers properly.

(2) Load charges carefully.

(3) Place primer properly.

(4) Perform any tamping operation with care to avoid damage to an otherwise carefully prepared charge.

1 Making cavity for cap in side



2 Placing and tying cap

Figure 22. Dynamite primed nonelectrically with cap in side.

3 Waterproofing

Figure 22—Continued.

(5) Fire the charge according to the proper technique.

(6) If possible, use dual firing systems (pars. 57–60). If both systems are properly assembled, the possibility of a misfire is reduced to a minimum.

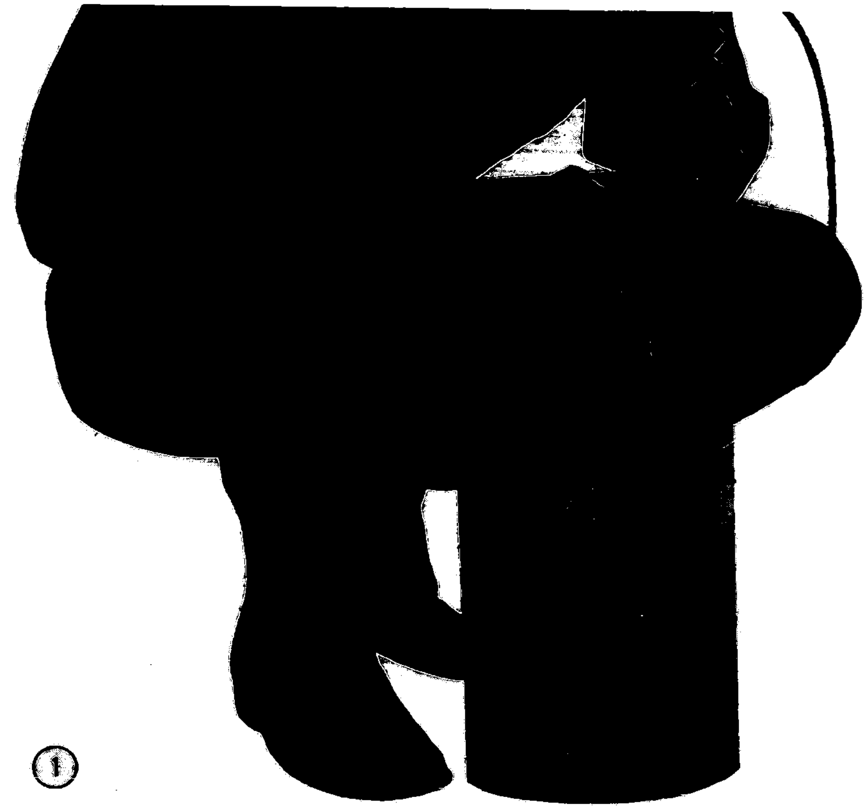
b. The Handling of Nonelectric Misfires. Occasionally, despite all painstaking efforts, a nonelectric misfire will occur. Investigation and correction should not be undertaken by a soldier inexperienced in the handling of explosives; for it is a hazardous operation that should be done only by a demolition specialist. For a charge primed with a nonelectric cap and time fuse, the procedure is as follows:

(1) Delay the investigation of the misfire at least 30 minutes from the expected time of detonation. This should be ample time for any delayed explosion to take place, because of a defective powder train in the fuse. Under certain combat conditions, however, immediate investigation, with great risk to the investigator, might be necessary.

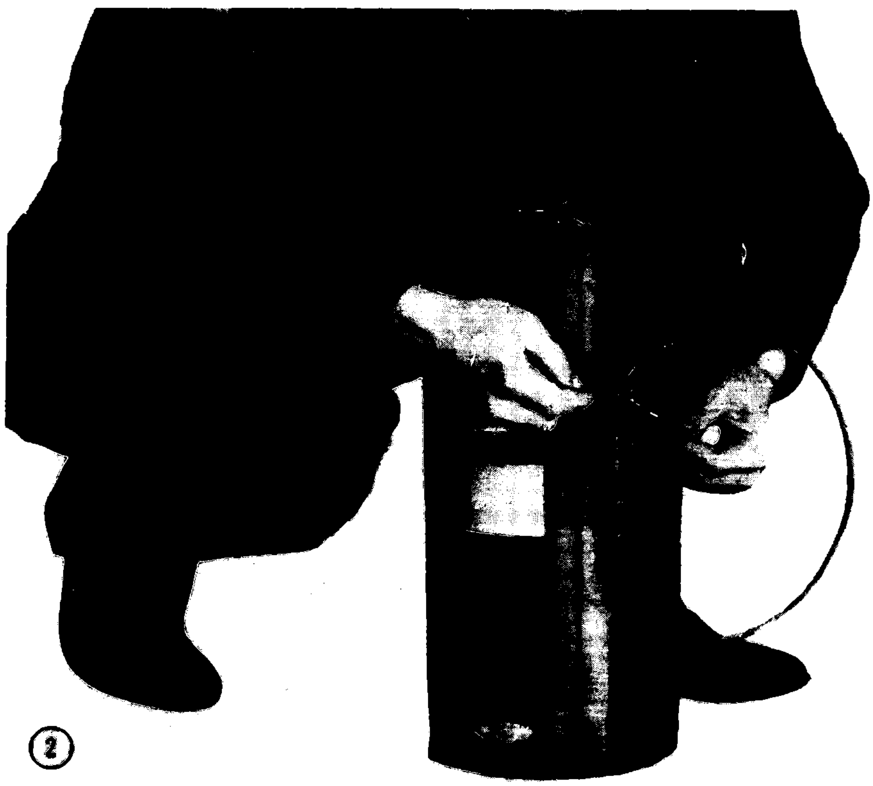
(2) If the misfired charge is not tamped, lay a new primer at the side of the charge and refire.

(3) If the misfired charge has only a foot or so of tamping, attempt to explode it by detonating a new 2-pound primer placed on top.

(4) If the misfired charge is located in a tamped borehole, or if the tamped charge is so situated as to make method (3) above impractical, remove the tamping by means of wooden or nonmetallic tools to avoid accidentally digging into the charge and detonating it. Also, the tamping may be blown out by means of a stream of compressed air or water if either is available. Use stiff rubber hose in this operation. Constant checking of the depth of the borehole from the ground surface or the top of the charge during digging will minimize the danger of striking the charge. When the charge has been uncovered within 1 foot, insert and detonate a new 2-pound primer.



1 Inserting cap in well



2 Tying fuse to cleat

Figure 23. Nonelectric priming of ammonium nitrate cratering charge.

(5) An alternate method of reaching a deep misfired charge is to drill a new hole within a foot of the old one and to the same depth. A 2-pound prime charge is then placed in the new hole to detonate the misfired charge. Extreme care is required in drilling the new hole to avoid striking the old misfired charge or placing the new charge too far away to induce detonation.

36. Other Nonelectric Firing Accessories

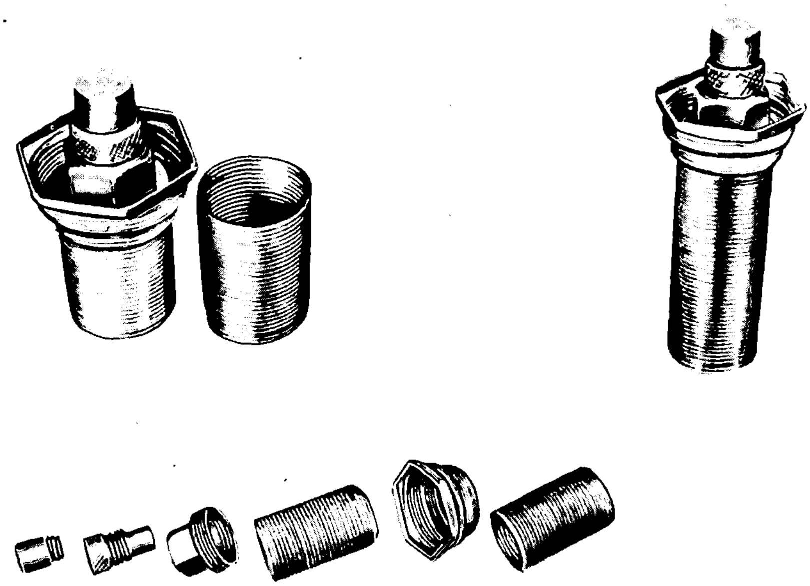
In addition to the nonelectric equipment described above, there are other items that may be used to advantage in nonelectric firing systems. These are—

a. M10 Universal High Explosive Destructor.

(1) *Description.* The M10 destructor is a high explosive charge in an assembled metal device initiated by means of blasting caps or mine activators with standard firing devices. The destructor has booster cups containing tetryl pellets. The chief function of the destructor is in the conversion of loaded projectiles and bombs to improvised demolition charges and in the destruction of abandoned ammunition (fig. 24).

(2) *Safety.* Observe safe distance requirements for the preparation of primers and demolition charges as directed in TM 9–1900, when using the M10 universal destructor.

b. M1 Concussion Detonator. The M1 concussion detonator is a mechnical firing device activated by the concussion wave of a nearby blast (fig. 25). It fires several charges simultaneously without connecting them with wire or detonating cord. A single charge fired in any way in water or air will detonate all charges primed with concussion detonators within range of the main charge or of each other (table I). Methods of use are presented in TM 9–1946. Detonators frequently function at ranges greater than those in table I, but their reliability is then not assured. They should not be used in

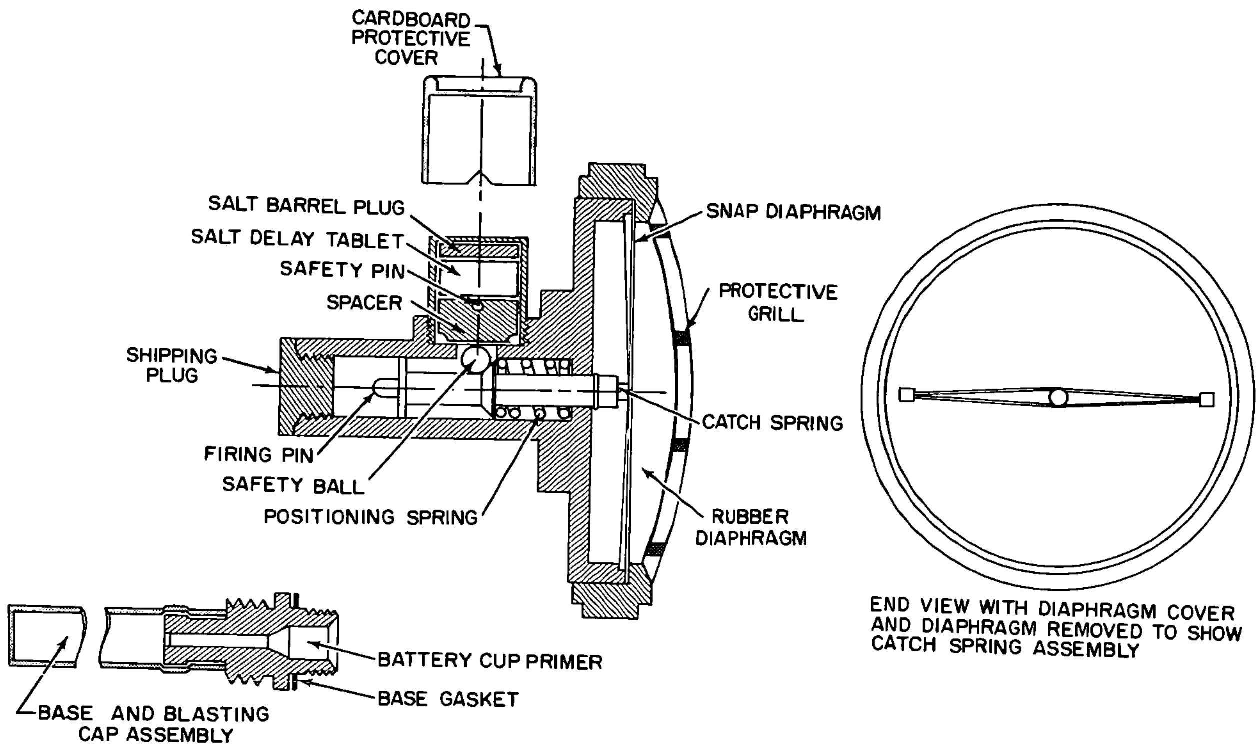


UPPER LEFT: ASSEMBLED DESTRUCTOR WITH 2ND BOOSTER CUP (EMPTY), APPROXIMATELY 3/8 ACTUAL SIZE.

UPPER RIGHT: DESTRUCTOR COMPLETELY ASSEMBLED, APPROXIMATELY 1/3 ACTUAL SIZE.

LOWER (FROM LEFT TO RIGHT): PRIMING ADAPTOR, BLASTING CAP BUSHING, ACTIVATOR BUSHING, BOOSTER CUP, AMMUNITION BUSHING, AND BOOSTER CUP. 1/4 ACTUAL SIZE.

Figure 24. M10 universal destructor.



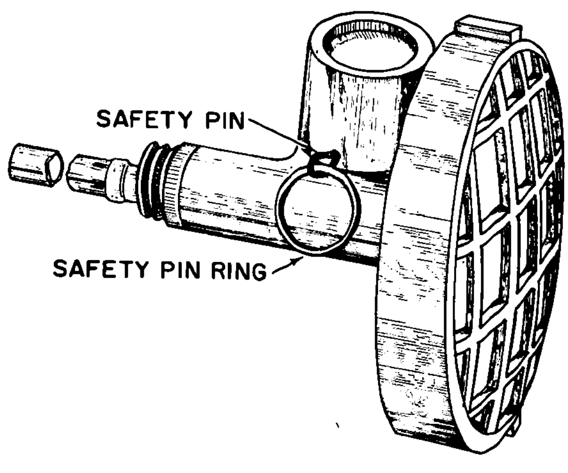


Figure 25. M1 concussion detonator.

surf at depths greater than 15 feet, as they function by hydrostatic pressure at a depth of 25 feet.

Table I. Operating Range of Concussion Detonators

Initiating charge (lbs)	In water		In air
	Depth of water (ft)	Recommended range (ft)	Recommended range (ft)
0.5	2	10	
0.5	4	50	
0.5	6	80	
0.5	8	80	
2.5			10
2.5	2	20	
2.5	4	80	
2.5	6	80	
2.5	8	150	
5			11
10			15
15			15
20			21
20	2	20	
20	4	80	
20	6	180	
20	8	260	

c. M1 Delay Firing Device. This device (fig. 26) has a time delay ranging from 3 minutes to 23 days, depending on the model and the prevailing temperatures. As the time delay interval may not be exact, the M1 should not be used if accuracy is demanded. The M1 delay type firing device consists of a tube containing a percussion cap, a spring-loaded striker held cocked by a restraining wire, and a glass ampoule filled with a corrosive solution. Threads on the base of the tube fit the threads on standard cap wells. A hole through the tube permits inspection to see whether or not the striker has been released prematurely. When the ampoule is crushed, the corrosive solution dissolves a portion of the restraining wire, releasing the striker. A colored identification and safety strip fits through the sides of the tube and prevents premature firing. Table II gives the delay time for fuzes of each color at different temperatures. A similar table is included in each box with the firing devices. The M1 firing device is prepared for use as follows:

(1) Consult table II for tab color giving the proper time delay at prevailing temperatures.

(2) Select a firing device with safety strip of tab color giving the proper time delay.

(3) Insert a nail through the inspection hole or by visual inspection make certain that the striker has not been released.

(4) Inspect the portion containing the ampoule to see whether or not it has been crushed

(5) Crimp a nonelectric military blasting cap to the base of the firing device.

d. Mine and Boobytrap Firing Devices. Standard mine and boobytrap fuzes and firing devices and their uses are found in FM 5-31, TM 9-1940, and TM 9-1946. They include the following general types:

(1) *Pull.* The M1 pull firing device is initiated by a pull on a tripwire.

(2) *Pressure.* The M1A1 pressure firing device functions by pressure.

(3) *Pressure-release.* The M5 pressure-release firing device functions when pressure is released from it.

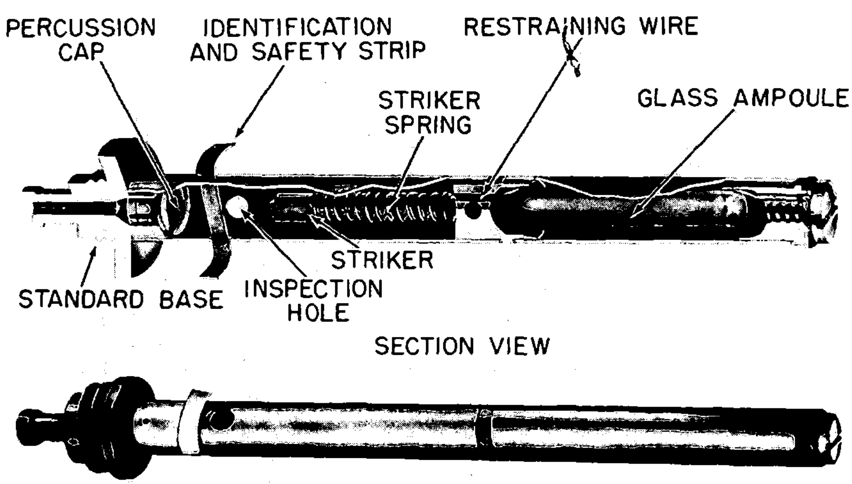


Figure 26. M1 delay firing device.

Table II. Temperature Corrections

Degree F	Black	Red	White	Green	Yellow	Blue
150	5 min.	4 min.	25 min.	¾ hr.	¾ hr.	1½ hrs.
130	7 min.	6 min.	37 min.	1 hr.	1 hr.	2¾ hrs.
110	8 min.	7 min.	50 min.	1½ hrs.	2 hrs.	5 hrs.
90	10 min.	10 min.	1 hr.	2¼ hrs.	4 hrs.	9½ hrs.
70	12 min.	14 min.	1¾ hrs.	4 hrs.	6¼ hrs.	17½ hrs.
50	14 min.	21 min.	3¾ hrs.	8½ hrs.	8¼ hrs.	45 hrs.
30	1 hr.	½ hr.	7½ hrs.	18 hrs.	16½ hrs.	5 days
10	5 hrs.	1 hr.	11 hrs.	38 hrs.	4 days	9 days

Caution: **The above times are average only. Actual firing may be approximately 50 percent, plus or minus, of the times indicated.**

(4) *Combination.* The M3 pull-release firing device functions when a taut tripwire is either pulled or cut. Also, two or more devices may be installed on a single charge so that firing may result by any combination of the above actions.

Section II. ELECTRIC FIRING SYSTEM

37. System Components and Assembly for Detonation

The electric firing system provides the electric spark or impulse to initiate detonation. The electric impulse travels from the power source through the lead wires to fire the cap. The chief components of the system are the blasting cap, firing wire and reel, and the blasting machine. The preparation of the explosive charge for detonation by electrical means is called electric priming. The components of the electric system and the priming methods are described below in the order of assembly and preparation for detonation.

a. Attaching the Electric Blasting Cap.

(1) *Types of blasting caps.* Two types of electric blasting caps are in use—military and commercial. These are also of two types—instantaneous and delay.

(*a*) *Instantaneous.* The military instantaneous electric blasting caps are type II (J 2 PETN) and M-6 (RDX). These have 12-foot electric leads for attaching to a firing wire and then to a blasting machine or other source of power for detonation. Commercial electric blasting caps No. 6 and No. 8 have three lengths of leads—short (4–10 feet), medium (12–40 feet), and long (50–100 feet). The lead wires of the commercial blasting cap enter through a seal made either of sulphur, rubber, or plastic. A short-circuit tab or shunt fastens the loose ends of the wires together, preventing accidental firing. Figure 11 shows the construction details of a typical electric blasting cap.

(*b*) *Delay.* Military electric delay blasting caps are shown in figure 27. They consist of 1st, 2d, 3d, and 4th delay types with approximate time delays of 1 second, 1.18 seconds, 1.35 seconds, and 1.53 seconds, respectively. Commercial delay caps up to 10th delay (approximately 2.5 seconds) are available but not issued by the military. The commercial millisecond electric delay cap is available also, but not issued.

(2) *Caps tested before use.* Caps are tested before use by means of a galvanometer. After first testing the galvanometer (par. 45), and then removing the short-circuit shunt from the electric blasting cap ((1)(*a*) above), connect one post of the galvanometer to one cap lead wire and the other post to the other lead wire. If the instrument registers a flowing current, the blasting cap is satisfactory; if not, the cap is defective and should not be used. Destroy defective caps by placing them in the charge to be detonated. If a battery other than that recommended is placed in the galvanometer, it might easily detonate the blasting cap. During the test, *always point the explosive end of the blasting cap away from the body.*

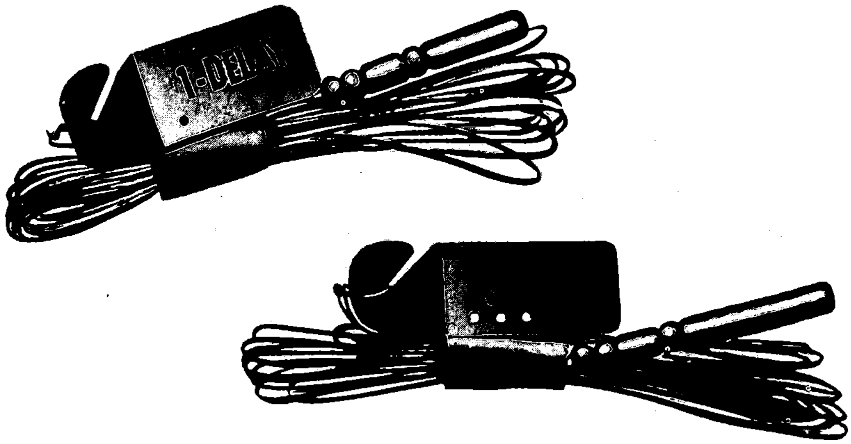


Figure 27. Electric delay blasting caps.

(3) *Precautions—two or more caps.* If two or more electric blasting caps are connected in the same circuit, be sure that they are made by the same manufacturer. This is essential to prevent misfires, as blasting caps of different manufacturers have different electrical characteristics. Blasting caps of a similar manufacturer may be identified by the label, color of the cap, or shape of the shunt.

(4) *Use of electric blasting cap with priming adapter.* The blasting cap wires are passed through the slot of the adapter (fig. 13) and the cap is pulled into place in the adapter. The cap is then inserted into the cap well of the explosive and the adapter is screwed into place.

(5) *Use of electric blasting cap without priming adapter.* When priming adapters are not available or demolition blocks have no threaded cap wells, the electric cap is inserted in the cap well and the cap wires are tied around the block by two half hitches or a girth hitch (fig. 29). To prevent any pull on the cap, a small portion of slack wire is left between the blasting cap and the tie.

b. Making Wire Connections. The two cap lead wires and the two firing wires are bared at the ends and twisted together to form two connections, which are then insulated with friction tape. The types of firing wire in use and the reel on which they are wound are described below.

(1) *Types of firing wire.* Wire for firing electric charges is issued in 500-foot lengths. It is the two conductor, No. 18 AWG plastic-covered or rubber-covered type. It is carried on the reel unit RL39A, described below. Single-conductor No. 20 AW annunciator wire is issued for making connections between blasting caps and firing wire.

(2) *Reel unit RL39A.* This consists of a spool, a handle assembly, a crank, an axle, and two carrying straps (fig. 55). The fixed end of the wire is extended from the spool through a hole in the side of the drum and fastened to brass thumbnut terminals. The handles are made of two U-shaped steel rods. A loop at each end encircles a bearing assembly, which is a brass housing with a steel center to accommodate the axle. The crank is riveted to one end of the axle and a cotter pin is placed in the hole at the other to hold the axle in place.

c. Connecting the Blasting Machine. After the cap lead wires have been attached at one end of the firing wires, the other end is fastened to two posts provided on the blasting machine. For safety reasons, only one individual should be detailed to connect the blasting machine to the firing circuit and to fire the circuit. He should be responsible for the care of the blasting machine at all times during blasting activities. He also should either connect the blasting wires in the circuit or check their connection by on-the-spot visual examination. Blasting machines issued by the military are as follows:

(1) *Ten-cap blasting machines.* This is a small electric impulse-type generator that produces adequate current to fire electric caps. The blasting machine fires instantaneously up to ten caps connected in series when the

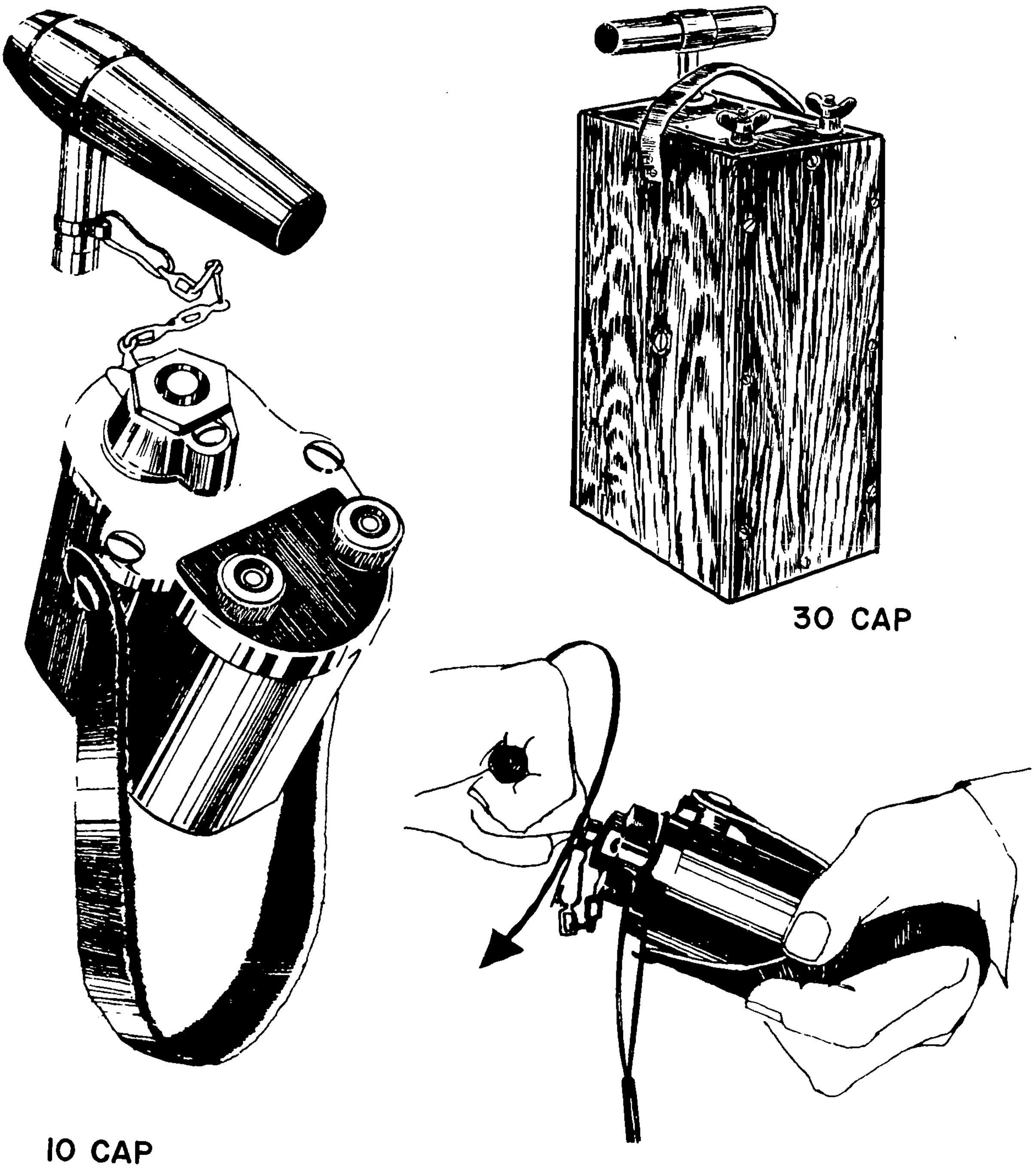


Figure 28. Blasting machines.

handle is rotated to the end of its travel. It weighs approximately 5 pounds. It should not be used, however, with parallel circuits (fig. 28). The operation is as follows:

(a) Check the machine to see whether or not it works properly. Operate it several times until it works smoothly before attaching the firing wires.

(b) Fasten the lead wires tightly to the terminals.

(c) Insert the handle.

(d) Insert the left hand through the strap and grasp the bottom of the machine.

(e) Grasp the handle with the right hand and turn it vigorously clockwise as far as possible.

(2) *Thirty-cap blasting machine.* This machine fires 30 electric caps connected in series (fig. 28). It weighs about 20 pounds. Operation is as follows:

(a) Raise the handle to the top of its stroke.

(b) Push the handle down quickly as far as it will go.

(3) *Fifty-cap and one-hundred-cap blasting machines.* These two are similar to the 30-cap machine except for size and weight and are operated in the same manner. They are adequate for firing their rated capacity of electric blasting caps connected in series.

38. Electric Priming of TNT and M2 Demolition Blocks

If priming adapters are available, prime demolition blocks with threaded cap wells (fig. 29) with an electric blasting cap in the manner described in paragraph 37*a*(4). If priming adapters are not available or if the demolition blocks have no threaded cap wells, insert the electric cap in the cap well and tie the cap wires around the block by two half hitches or a girth hitch (fig. 29). To prevent pull on the cap, always leave a small portion of slack wire between the blasting cap and the tie.

39. Electric Priming of M1 Chain Demolition Block

Electric priming of M1 chain demolition blocks is no different from nonelectric priming (par. 31), except that an electric blasting cap instead of a nonelectric blasting cap and a time fuse are used.

40. Electric Priming of Plastic Explosives

Plastic explosives (Composition C3 and C4) are primed electrically in the same manner that they are primed nonelectrically (par. 32), except that an electric blasting cap is used.

41. Electric Priming of Dynamite

Dynamite is primed electrically in the same way as nonelectrically, except that the blasting cap is held in place by tying the lead wires around the cartridge with a girth hitch or two half hitches (fig. 30).

42. Electric Priming of Ammonium Nitrate and Nitramon Cratering Charges

An electric blasting cap is placed in the cap well and the lead wires are looped around the cleat above it.

43. Circuits

Three types of circuits have been found effective for firing demolitions explosives—series, parallel, and series-parallel. The series circuit is the most generally used, and adequate equipment for dependable firing is issued. The other circuits, while equally effective, are more complex to set up and under ordinary conditions require a source that provides a more continuous flow of power than the impulse obtained from the standard blasting machine. These circuits are described as follows:

a. Series Circuit. This is used for connecting two or more charges fired electrically by a blasting machine (fig. 31). Charges are connected in series

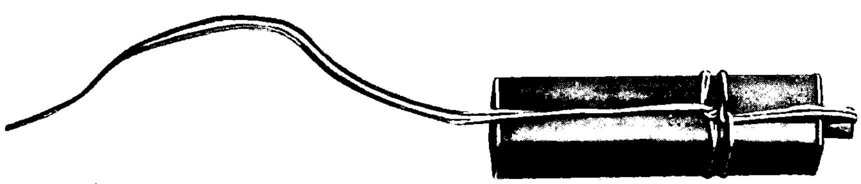


Figure 29. Electric priming of 1-lb TNT block.

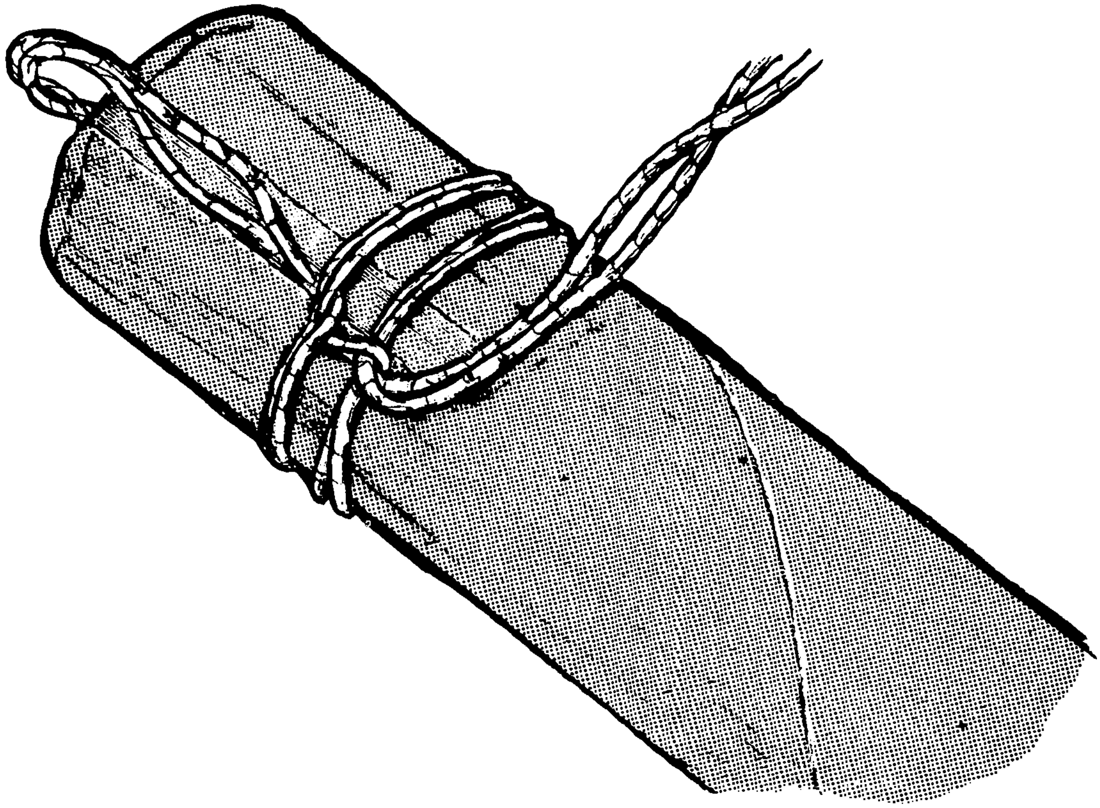


Figure 30. Electric priming of dynamite.

by connecting one blasting cap lead wire from the first charge to one lead wire in the second charge and so on until only two end wires are free, then connecting the free wires to the ends of the firing wire. Connecting wires (usually annunciator wire) are used when the distance between blasting caps is greater than the length of the usual lead wires. Also, the "leap frog" method of connecting caps in series (fig. 31) is useful for firing a long line of charges. This method consists merely of omitting alternate charges on the way and then connecting them to form a return path for the electric impulse to reach the other lead of the firing wire. This brings both end wires out at the same end of the line of charges, and thus eliminates laying a long return lead from the far end of the line of charges back to the firing wire.

Note. Only series circuits are recommended for use for firing by blasting machine.

b. Parallel and Series-Parallel Circuits. A parallel electrical circuit (fig. 31) or a series-parallel electrical circuit (fig. 31), is used in the firing of explosives only when an adequate power source is available. These circuits should be used only by a skilled blaster; for they must be accurately balanced to insure the detonation of all charges. Inaccurate balancing may cause a misfire. Power requirements for multiple firing circuits are found in appendix V. *Blasting machines should not be used to fire parallel and series-parallel circuits.*

44. Splicing of Electric Wires

Insulated wires, before splicing, must have the insulating material stripped from the ends, exposing about 3 inches of bare wire (1, fig. 32). All enamel also must be removed from the bared ends by carefully scraping them with the back of a knife blade or other suitable tool, but not nicking, cutting, or weakening them. Stranded wires, after scraping, should be twisted tightly.

a. Splicing Methods. Two wires, having been prepared as described above, may be spliced, as follows:

(1) Point the free ends in opposite directions (1, fig. 32), join them with a few tight twists around each other, and bend the remaining ends up, away from the joint (2, fig. 32). Then twist these ends to form a "pigtail" (3, fig. 32), which is at right angles to the connected wires. Push

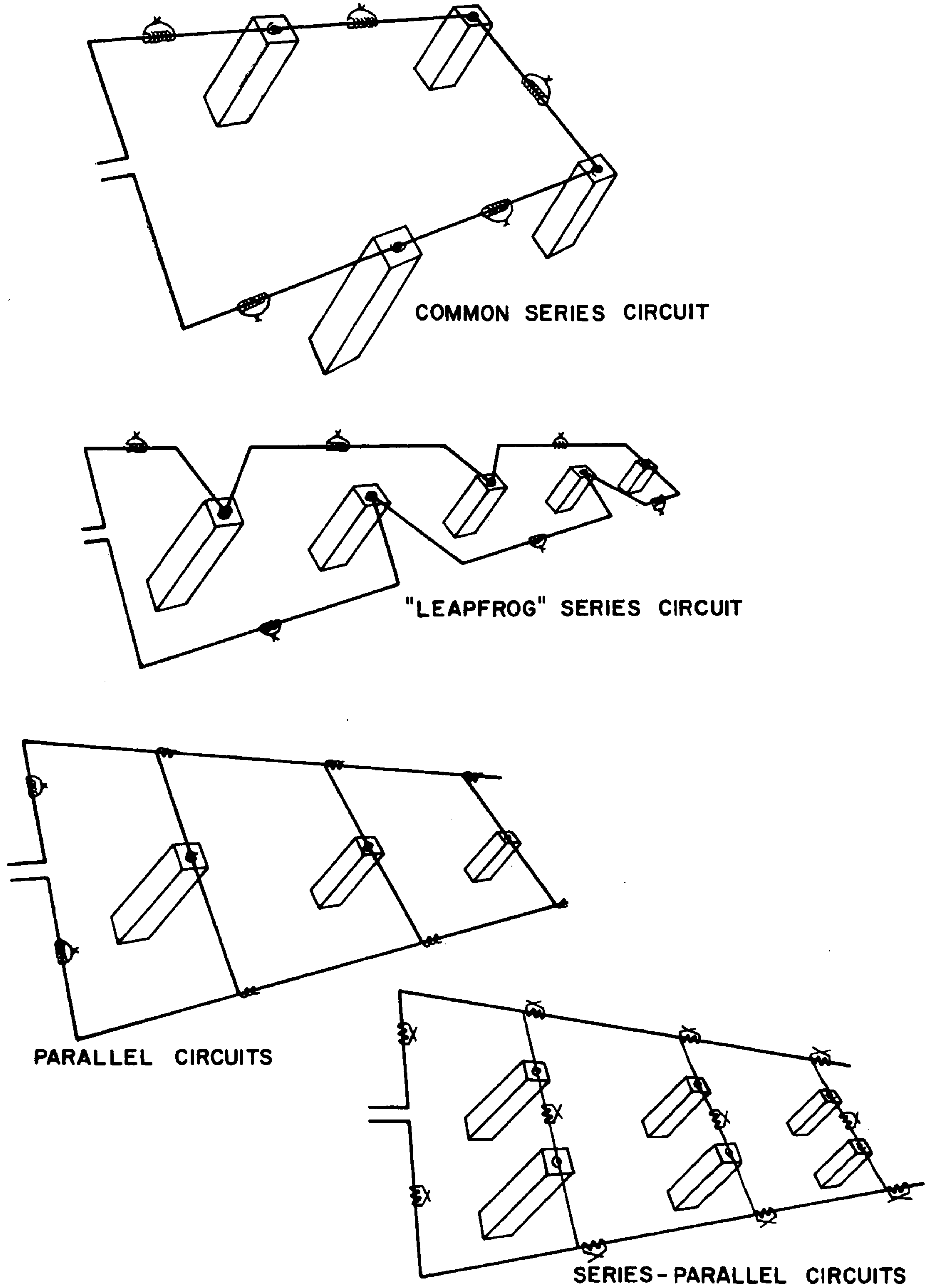
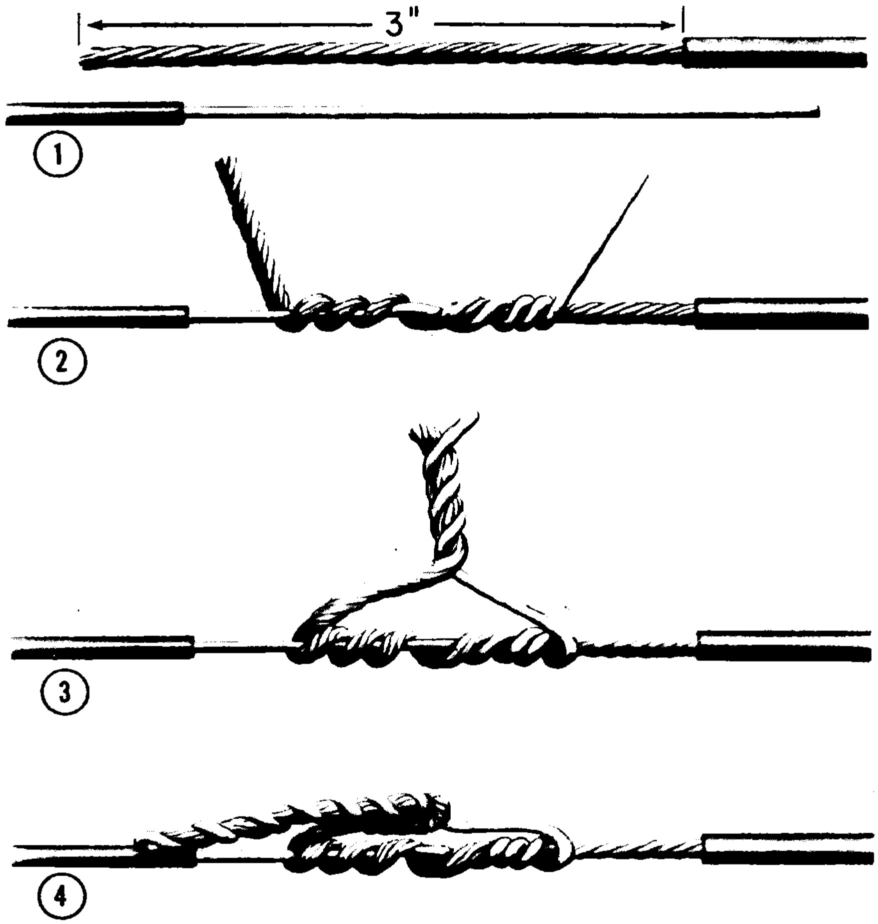


Figure 31. Circuits.



1 Stripping wires
2 First step of splice
3 Second step of splice
4 Completed splice

Figure 32. Wire-splicing method.

the "pigtail" to one side to lie along one of the wires before taping (4, fig. 32). This is known as the Western Union splice.

(2) Place the two wires to be connected side by side with the free ends pointing in the same direction. Bend these ends to form a short crank and wind them together by twisting. This forms a tight connection that becomes tighter if pulled. As this connection is formed at right angles to the wire, it should be bent along one side of one wire before taping.

(3) Place the two free ends side by side and bend about half of these free ends back onto the other half. Then grasp the loop thus found with the thumb and forefinger of one hand while holding the running end of the wires with the other hand and twist the loop to join the wires. This splice is more bulky than that in (1) above, but it is quickly done and efficient. To tape the splice, pinch the sides of the loop together, reshaping it to form a neatly taped connection.

(4) Any splicing method, instead of 1 to 3, will probably be satisfactory if it does not appreciably reduce the tensile strength of the wire or does not materially increase the electrical resistance.

b. Staggered Splices. Join one pair of electrical conductors to another pair by splicing the individual wires to one another (one of one pair to one of another pair, and the second of one pair to the second of the other). In order to prevent a short circuit at the point of splice, stagger the two separate splices and tie with tape as in 1, figure 33. An alternate method of preventing a short circuit at the point of spice is shown in 2, figure 33, where the splices are separated, not staggered.

c. Protection of Splices. Protect all bare wire splices in wiring circuits to prevent their short-circuiting to the ground or to each other. Whenever possible, insulate them from the ground or other conductors by wrapping them with friction tape or other electric insulating tape. This is particularly necessary when splices are placed under wet tamping. Circuits, not taped or insulated, lying on moist ground must be supported on rocks, blocks, or sticks so that only the insulated portion of the wires touches the ground.

45. Use of the Galvanometer in Testing

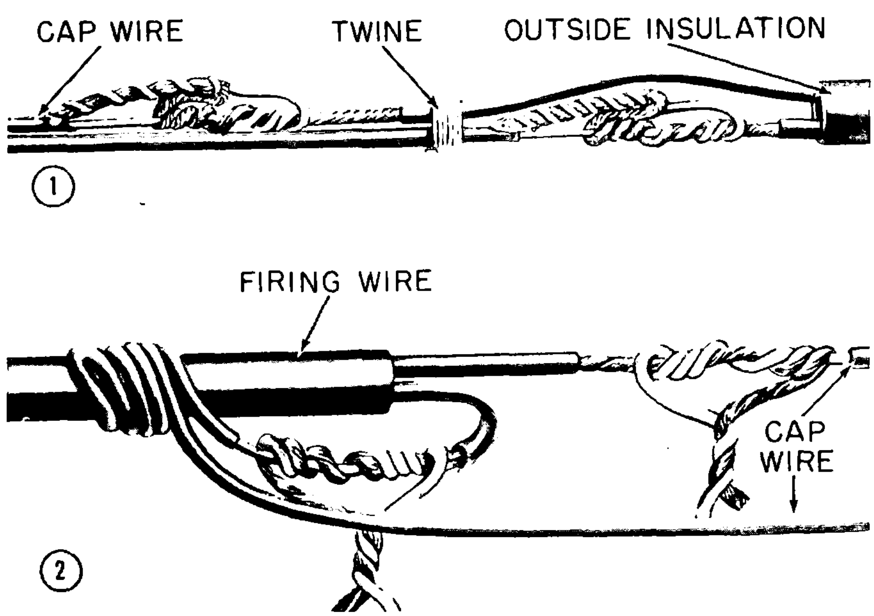
The galvanometer is an instrument used in testing the electric firing system to check the functioning of the various parts, such as blasting cap, firing wire, wire connections, splices, and circuits in order to reduce the possibility of misfires (fig. 55). Its components include an electromagnet, a small special silver-chloride dry cell, a scale, and an indicator needle. When the two external terminals are connected in a closed circuit, the flow of current from the dry cell moves the needle across the scale. The extent of the needle deflection depends on the amount of resistance in the closed circuit and on the strength of the cell. The galvanometer must be handled carefully and kept dry. It should be tested before using by holding a piece of metal across its two terminals. If this does not cause a wide deflection of the needle, the cell is weak and must be replaced. Being delicate, the instrument must not be opened except to replace a weak cell. When used in a cold climate, the galvanometer should be protected from freezing by keeping it under the clothing near the body, as dry cells tend to cease functioning at temperatures below 0° F.

***Caution:* Only the special silver chloride dry cell battery BA245/U is to be used in the galvanometer, as other cells may produce sufficient voltage to detonate the blasting caps.**

a. Testing Firing Wire. In the testing of wire or circuits, test the galvanometer first as described above. Firing wire may be tested on the reel; but it must be tested again after unreeling, as uncoiling may separate broken wires, unnoticeable when reeled.

(1) Separate the firing wire at both ends. Touch the wires at one end to the galvanometer posts. The needle should not move. If it does, there is a short circuit in the firing wire.

(2) Twist the wires together at one end and touch those at the other end to the galvanometer posts. This should cause a wide deflection of the needle. No movement of the needle indicates a break in the firing wire, while a slight movement indicates a point of high resistance in the circuit.



1 Staggered splice   2 Separated splice

Figure 33. Splicing two pairs of wires.

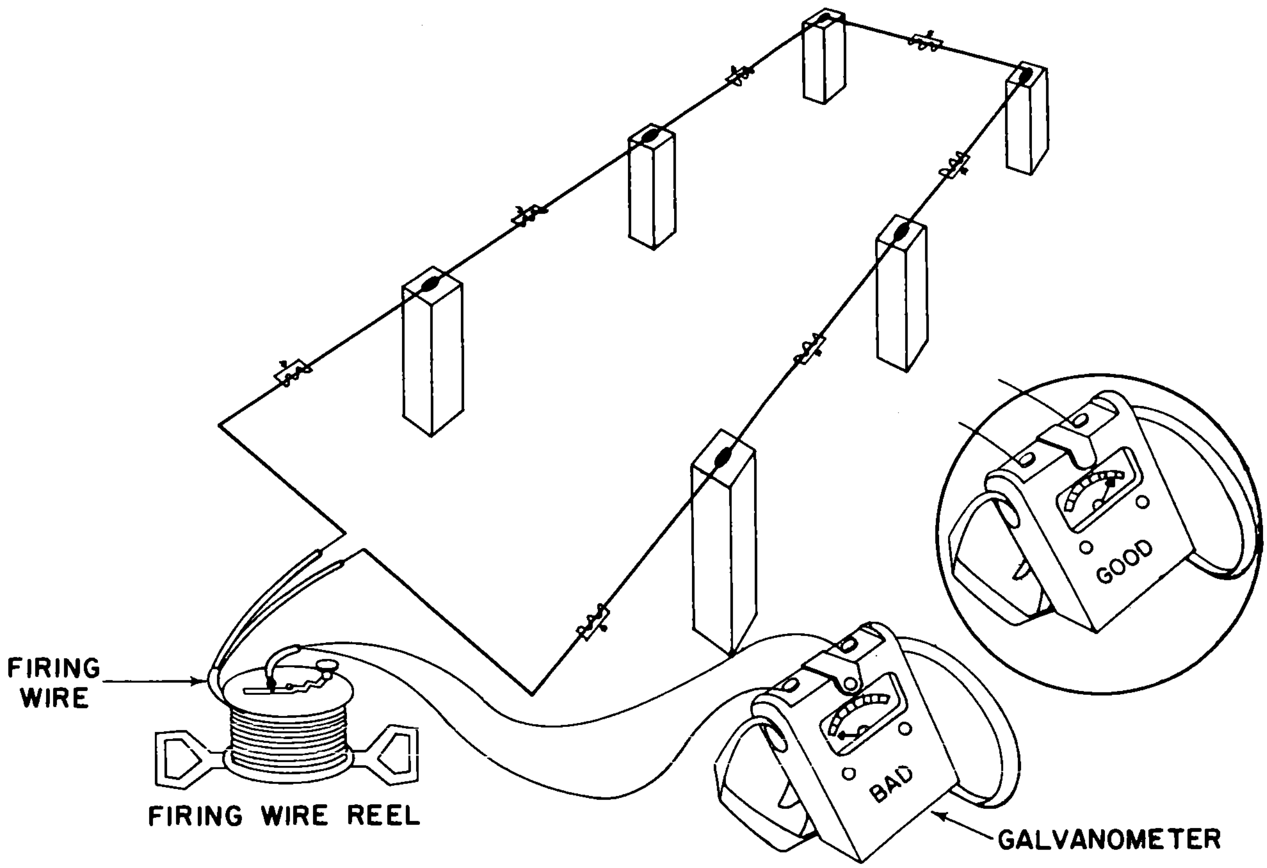


Figure 34. Testing firing circuit.

b. Testing Entire Circuit.

(1) *Limitations of the test.* The test of the entire circuit reveals the breaks, if any; but this will not detect short circuits or guarantee the inclusion of all charges in the circuit. Short circuits and omissions, however, are prevented by making the connections carefully and by visual checking before firing the charge. All joints and bare sections must be separated and placed out of contact with the ground and all other conductors.

(2) *The test.* After the entire circuit, including the firing wire, has been connected, test the circuit by touching the ends of the firing wire to the galvanometer terminals (fig. 34). If the needle does not move across the scale, there is a break in the circuit; if it does move across the scale, the circuit is complete. The amount of movement or deflection of the needle depends on the length of the firing wire and the number of blasting caps in the circuit. If the test indicates a break, it is located and corrected.

c. Locating a Break. Breaks usually occur in the firing wire or at the splices.

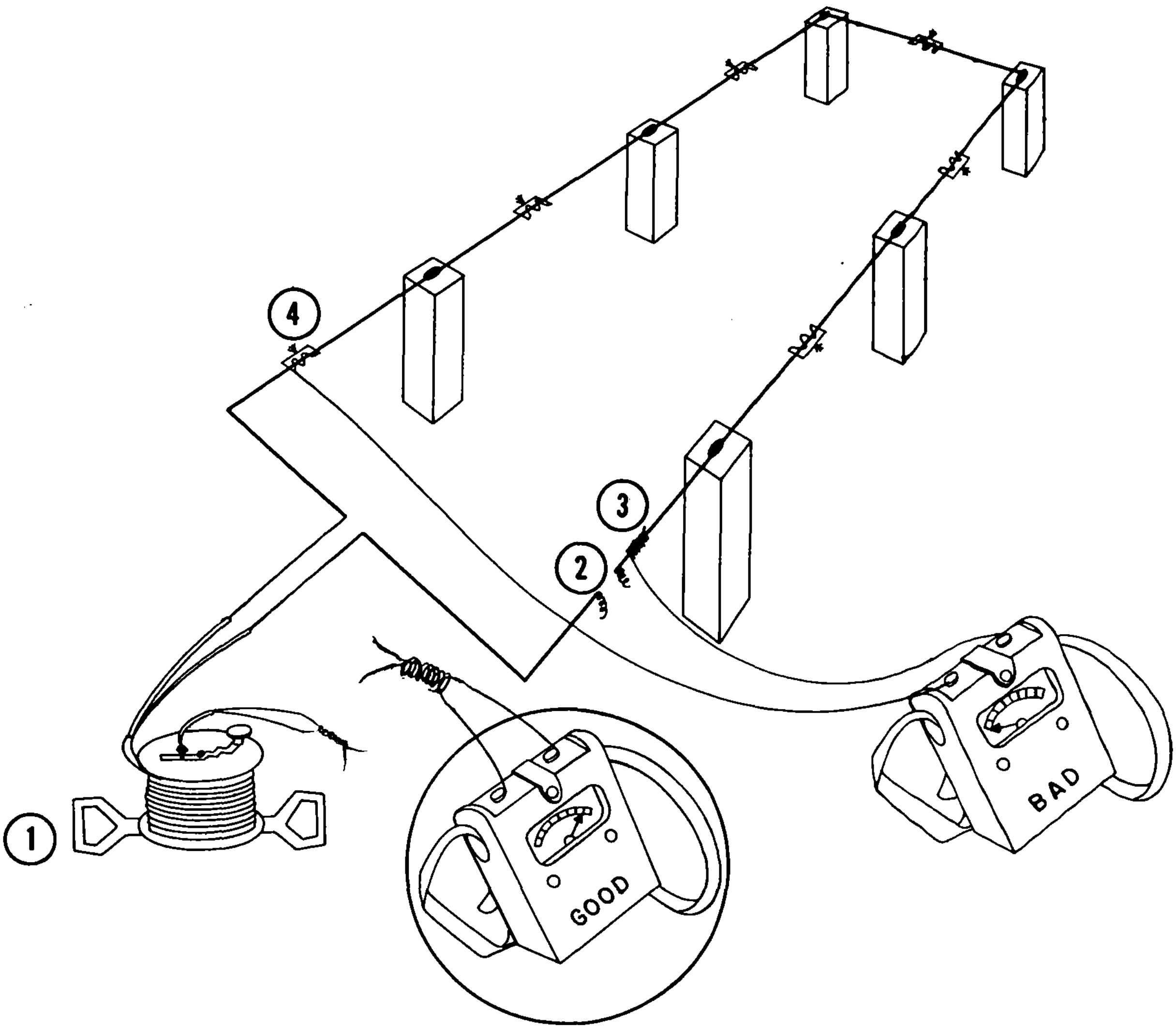
(1) *Testing splices at the end of the firing wire.*

(*a*) Disconnect the firing wire ends from the blasting machine and splice them together (1, fig. 35).

(*b*) Open the circuit by disconnecting the splice that joins the first blasting cap lead wire to one firing wire (2, fig. 35).

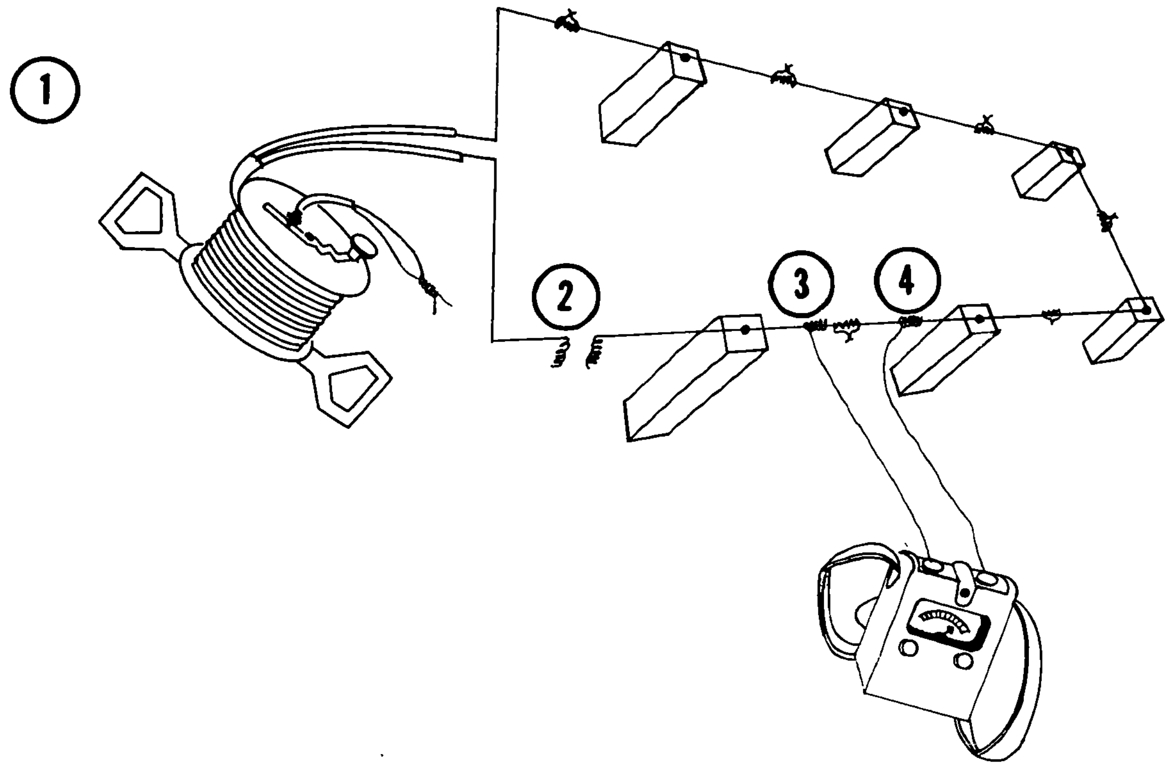
(*c*) Touch one galvanometer lead wire to the blasting cap lead wire that has just been disconnected from the firing wire (3, fig. 35).

(*d*) Touch the other galvanometer lead wire to the blasting cap lead wire just before its splice with the other firing wire (4, fig. 35). If the galvanometer now registers a current, a break exists at one or both splices at the end of the firing wire.



1 Splice of firing wires from blasting machine
2 Open circuit
3 One galvanometer lead connected to blasting cap lead wire
4 The other galvanometer lead connected to last blasting cap

Figure 35. Testing splices at end of firing wire.



1 Splice of firing wires from blasting machine
2 Open circuit
3 One galvanometer lead connected to one side of splice
4 One galvanometer lead connected to other side of splice

Figure 36. Testing individual splices.

(2) *Testing individual splices.*

(*a*) Repeat (1)(*a*) and (*b*) above (1, 2, fig. 36).

(*b*) Place one galvanometer lead wire on one side of a splice (3, fig. 36), and the other galvanometer lead wire on the other side (4, fig. 36).

(*c*) If the galvanometer needle moves across the scale as it did during the testing of the galvanometer by short circuiting the terminals, the splice is satisfactory.

(*d*) Repeat the test for each splice until all breaks have been located and corrected.

(3) *Testing individual primers (including leads to primers).*

(*a*) Repeat (1)(*a*) and (*b*) above (1 and 2, fig. 37).

(*b*) Place the galvanometer leads across each primer from one splice point to the next (3 and 4, fig. 37).

(*c*) Check similarly all connecting wires inserted between the leads.

(*d*) If there is no deflection of the instrument needle, there is a break in that portion of the circuit.

(4) *Alternate method.*

(*a*) Repeat (1)(*a*) and (*b*) above, (1 and 2, fig. 35).

(*b*) Connect one galvanometer lead to the circuit at successive points (usually just beyond the splices to include one or more splices in the tested portion of the circuit for each successive trial) until a break is indicated by the failure of the instrument needle to deflect.

(*c*) The break, therefore, is somewhere between the point where the moving instrument lead is located and the last point where the moving lead was located without indicating a broken circuit.

d. Repairing the Circuit. If a splice is found defective, resplice the wires. If a cap is found defective, replace it. Then test the entire circuit again to make sure that all breaks have been located before attempting to fire the charge.

46. Electric Misfires

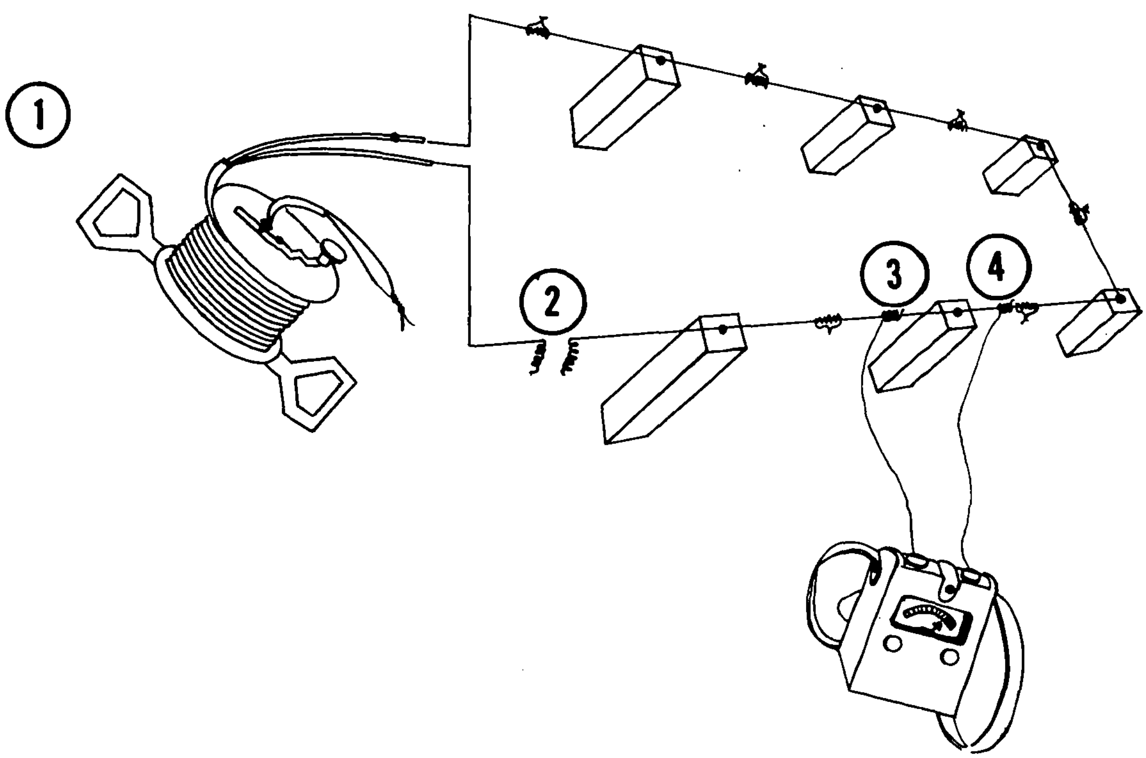
a. Prevention of Electric Misfires. In order to prevent misfires, make one demolition specialist responsible for all electrical wiring in a demolition circuit. He should do all splicing to be sure that—

(1) All blasting caps are included in the firing circuit.
(2) All connections between blasting cap wires, connecting wires, and firing wires are properly made.
(3) Short circuits are avoided.
(4) Grounds are avoided.
(5) The number of blasting caps in any circuit does not exceed the rated capacity of the blasting machine on hand.

b. Cause of Electric Misfires. Common specific causes for electric misfires include—

(1) Inoperative or weak blasting machine.
(2) Incorrect operation of blasting machine.
(3) Electric blasting caps that are too weak to detonate the explosive.
(4) Incorrect electric connections, causing either a short circuit, a break in the circuit or high resistance with resulting low current.
(5) Damaged electric firing circuits.
(6) The use, in the same circuit, of electric blasting caps made by different manufacturers.
(7) The use of more blasting caps than the power source rating.

c. Handling Electric Misfires. Because of the hazards of burning charges and delayed explosions, electric misfires must be handled with extreme caution. A burning charge may occur with the use of electric as well as nonelectric caps. Misfires of charges primed with detonating cord fired by electric blasting caps are handled as described in paragraph 56. If the charge is dual-primed electrically, it will be necessary to wait 30 minutes before investigating to make sure that the charge is not burning. An electric misfire, on the other hand, may be investigated immediately if the system is above ground and the charge is not dually primed with a nonelectric primer. If the system is below ground and primed only electrically, proceed as follows—



1 Firing wire connected to blasting machine
2 Open circuit
3 One galvanometer lead connected to one blasting cap lead wire
4 One galvanometer lead connected to next blasting cap lead wire

Figure 37. Testing individual primers.

(1) Check the firing wire connections to the blasting machine terminals to be sure that the contacts are good.
(2) Make two or three more attempts to fire the circuits.
(3) Disconnect the blasting machine firing wire and allow an elapse of 30 minutes before further investigation.
(4) Check the entire circuit, including the firing wire, for breaks and short circuits.
(5) If the fault is traced to a break or short circuit below the tamping—for example, below the ground surface in a borehole,—remove the tamping material very carefully to avoid striking the electric blasting cap.
(6) Make no attempt to remove either the primer or the charge.
(7) If the fault is not located by the removal of the tamping material to within 1 foot of the charge, place a new electric primer and 2 pounds of explosive at this point.
(8) Disconnect the blasting cap wires of the original primer from the circuit.
(9) Connect the wires of the new primer in their place.
(10) Replace the tamping material.
(11) Initiate detonation. Detonation of the new primer will fire the original charge.

Note. In some cases it may be more desirable or expedient to drill a new hole at a proper distance to avoid accidental detonation of the old charge and then place and prime a new charge.

47. Premature Detonation by Induced Currents and Lightning

a. Induced Currents. The premature detonation of electric blasting caps by induced radio frequency (RF) currents is possible. Table III, showing the minimum safe distance *versus* transmitter power, indicates the distance beyond which it is safe to conduct electrical blasting even under the most adverse conditions. Mobile type transmitters are prohibited within 150 feet of any electrical blasting caps or electrical blasting system. Two alternative courses of action may be taken when blasting at distances less than those shown in the table is necessary.

(1) The first alternative is a nonelectric blasting system, as there is no danger whatsoever of a premature detonation by RF current. This method should be used if at all possible.

Table III. Minimum Safe Distances for RF Transmitters

Fixed transmitters

Transmitter power (watts)	Minimum distance (feet)
5–25	100
25–50	150
50–100	220
100–250	350
250–500	450
500–1,000	650
1,000–2,500	1,000
2,500–5,000	1,500
5,000–10,000	2,200
10,000–25,000	3,500
25,000–50,000	5,000
50,000–100,000	7,000

(2) The second alternative is an electrical blasting system constructed and operated under the following rules to minimize the possibility of premature detonation by induced RF currents.
(*a*) Observe all electric blasting safety rules.
(*b*) Cover all firing wires with dirt.
(*c*) Use a regularly twisted wire like W–110/B or W–1–TT.
(*d*) Twist the full length of all cap lead wires when removing them from their original individual containers.
(*e*) Keep the number of caps at a minimum, preferably one.

b. Lightning. Lightning is a hazard to both electric and nonelectric blasting charges. A strike or a nearby miss is almost certain to initiate either type of circuit. Lightning strikes, even at remote locations may cause extremely high local earth currents and gradients that may initiate electrical firing circuits. The effects of remote lightning strikes are multiplied by proximity to conducting elements, such as those found in buildings, fences, railroads, bridges, streams, and underground cables or conduit. Thus electric and nonelectric blasting activities should be suspended when electric storms come within a distance of 8 to 10 miles.

48. Components and Their Assembly for Detonation

The detonating cord system consists primarily of a nonelectric blasting cap, a length of detonating cord, and the means of initiating the detonating cord which may be an electric or nonelectric blasting cap. The components of the system are described below in their order of preparation and assembly for detonation.

a. Fastening the Cord to the Charge. Priming is the securing of the detonating cord, with or without a nonelectric blasting cap, to the explosive charge, plus the means of initiation—an electric blasting cap or a nonelectric blasting cap and time fuse. This may be done with or without a priming adapter.

(1) *Without priming adapter.* If a priming adapter is not available, or the demolition block has no threaded cap well, the detonating cord is tied securely around the explosive by a clove hitch with two extra turns (fig. 38). The cord must fit snugly against the block and the loops must be pushed close together.

(2) *Alternate methods without priming adapter.*

(*a*) An alternate method is to place a loop of detonating cord on the block as in 1, figure 39, then wrap the detonating cord four times around the block as in 2, figure 39, and finally draw the free end of the detonating cord through the loop as in 3, figure 39, and pull until it becomes tight.

(*b*) Another method is to take a piece of detonating cord approximately 4 feet long and lay one end at an angle across the TNT block (fig. 40). Then wrap the running end three times over this end and around the block and at the fourth turn slip the running end under

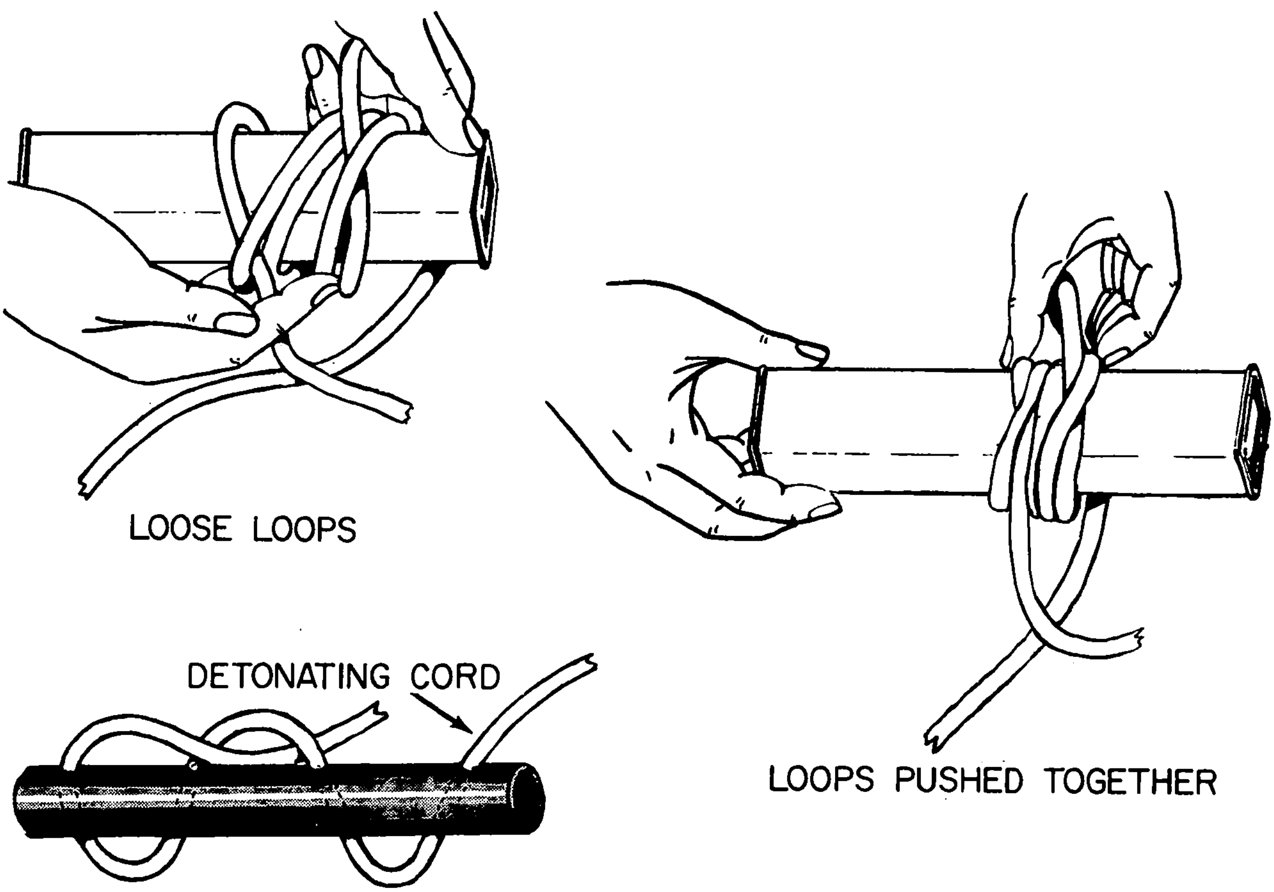


Figure 38. Priming TNT and dynamite with detonating cord.

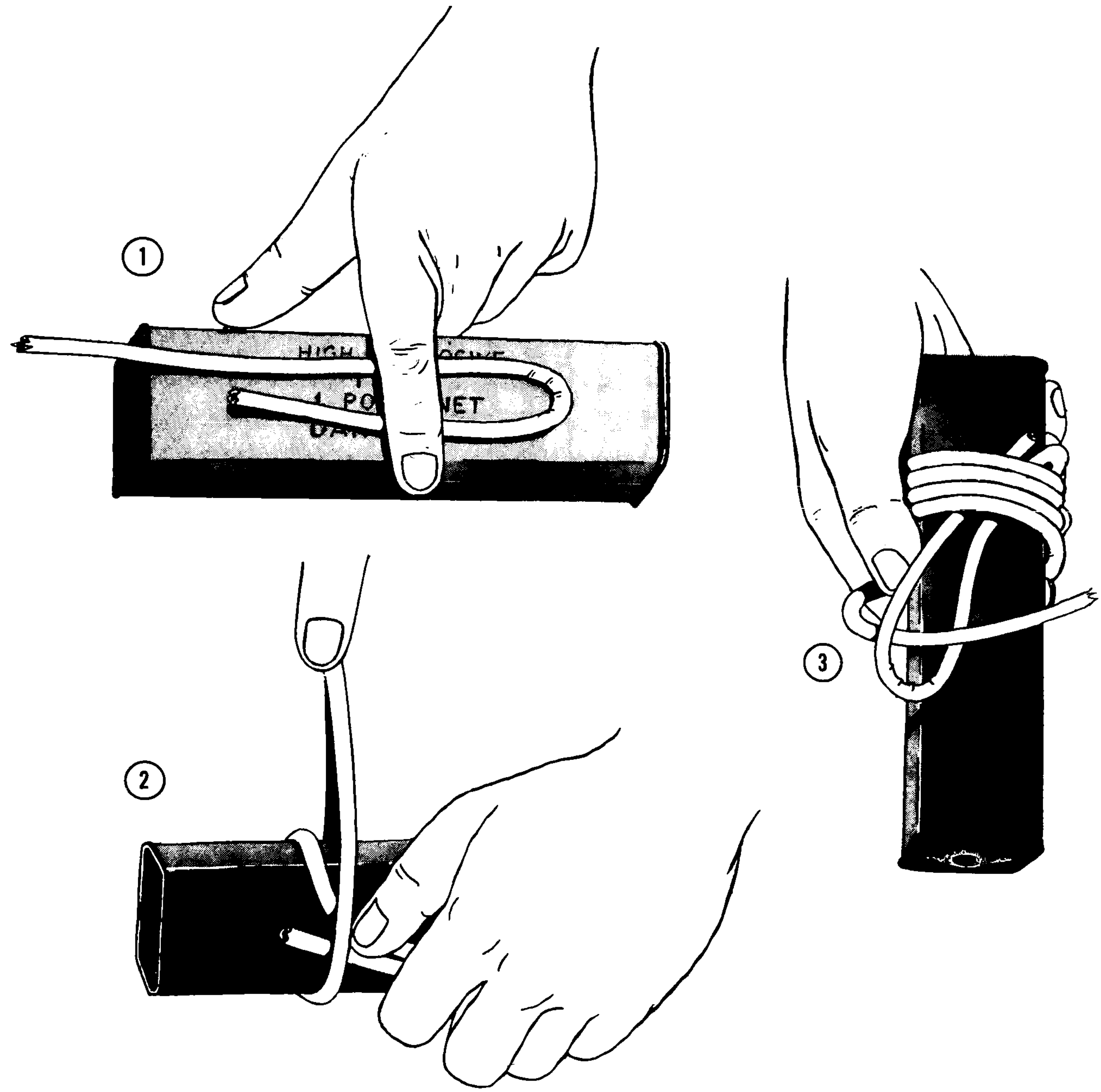


Figure 39. Alternate method (a) of priming TNT with detonating cord.

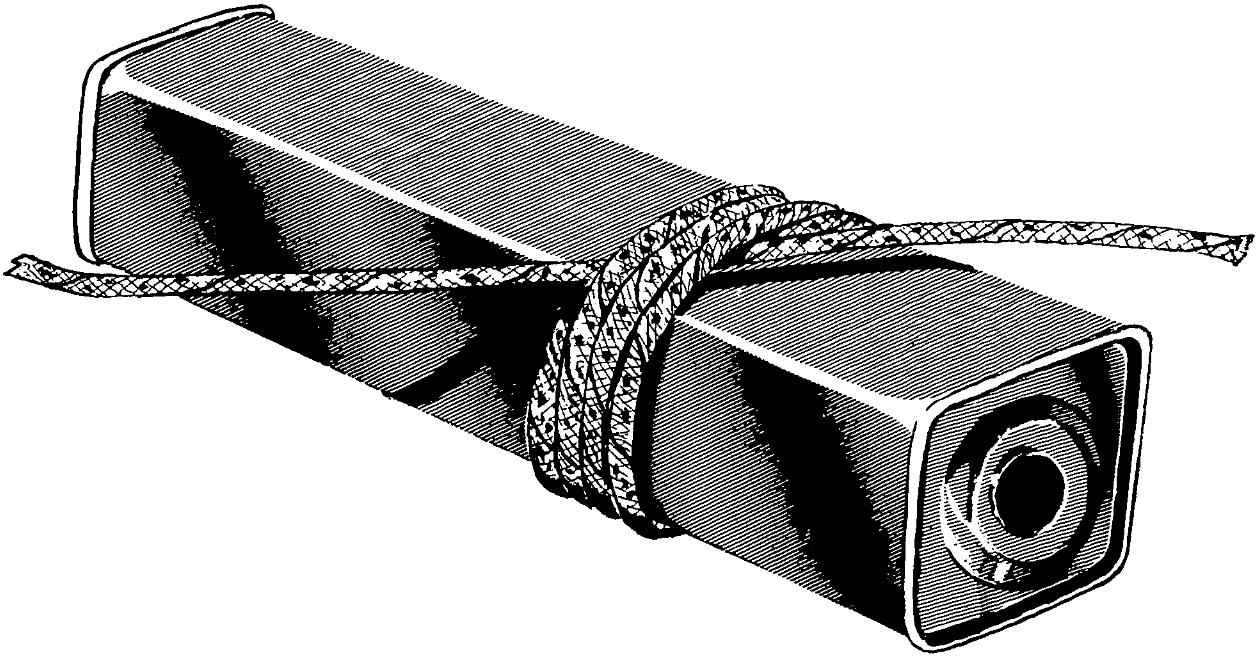
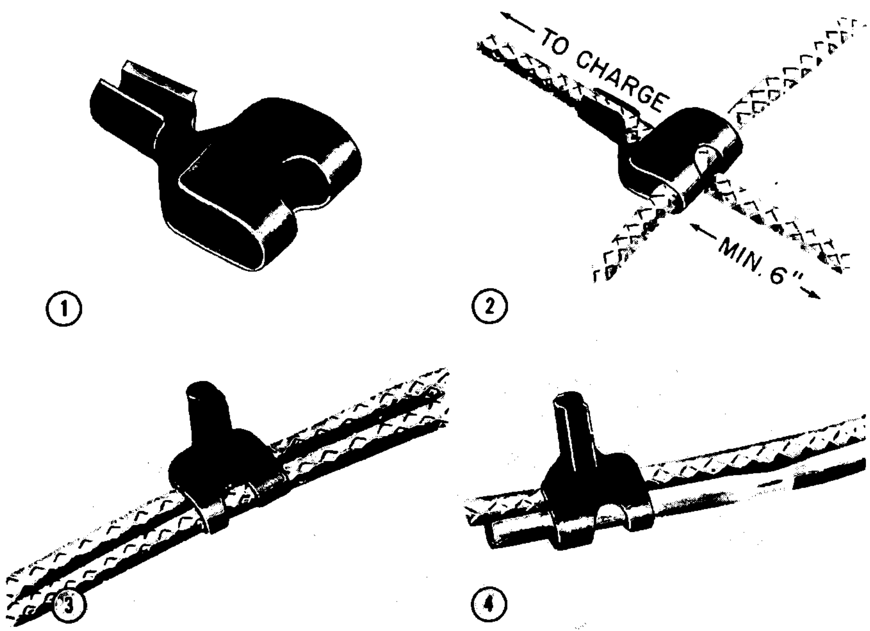


Figure 40. Alternate method (b) of priming TNT with detonating cord.



1 Detonating cord clip
2 Branch line connection
3 Connection of two detonating cord lines
4 Connection of blasting cap to detonating cord line

Figure 41. M1 detonating cord clip.

the three wraps parallel with the end laid at an angle and draw tight.

(3) *With priming adapter.* When a priming adapter is available, the detonating cord is slipped through the hole in the adapter and the nonelectric blasting cap is crimped onto the cord and placed in the threaded cap well, as described in paragraph 29. This method is recommended for charges placed above the ground.

b. Connection of Detonating Cord.

(1) *Use of M1 detonating cord clip.* The M1 detonating cord clip (fig. 41) is used to hold together two strands of detonating cord, either parallel or at right angles to each other, or to fasten a blasting cap to detonating cord. Connections are made more quickly with these clips than with knots. Also, knots may loosen and fail to function properly if left in place any length of time. Joints made with clips are not affected by long exposure.

(2) *Connecting branch lines of detonating cord.* Branch lines of detonating cord are connected by clipping the branch line with the U-shaped trough or the clip, and the main line with the tongue of the clip, as shown in 2, figure 41. The tongue is bent back, about 6 inches of the branch line is run through the trough end of the clip and the hole in the tongue, and the trough is then bent firmly around the cord. The main line is slipped over the branch line and under the tongue of the clip and held firmly by bending the tongue back into place.

(3) *Connecting two ends of detonating cord.* Ends of detonating cord are spliced by overlapping them about 12 inches, using two clips, one at each end of the overlap, and bending the tongue of the clips firmly over both strands. The connection is made secure by bending the trough end of the clip back over the tongue (3, fig. 41).

c. Priming Detonating Cord for Initiation.

(1) Detonating cord is primed for initiation by clipping or taping an electric or nonelectric

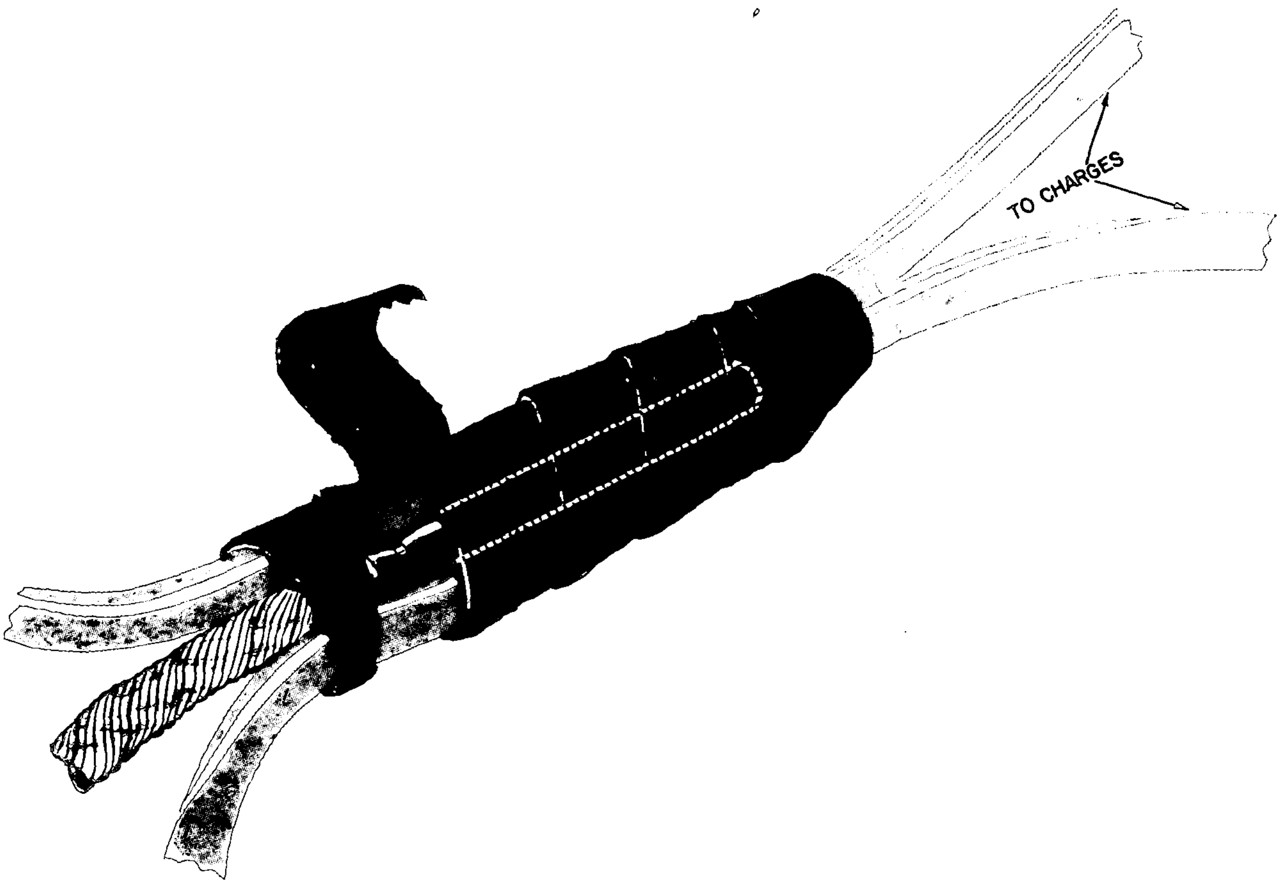


Figure 42. Method of fastening blasting cap to two lines of detonating cord.

blasting cap to it. The blasting cap, with its closed end pointed toward the charge, is placed about 6 inches from the end of the detonating cord and the clip is bent as shown in 4, figure 41. The trough is then bent back over the tongue to secure the connection. If more than one cap is used on a trunkline, the loaded end of the caps should all be pointed in the same direction, otherwise they may detonate only the cord between them but not the rest of the trunkline.

(2) A single electric or nonelectric blasting cap properly fastened to two detonating cord lines will detonate both. Figure 42 shows the correct method of fastening a cap to two lines.

49. Types of Detonating Cord

a. Description. This cord consists of a flexible tube filled with PETN encased in a white, yellow, or yellow-and-black waterproof covering. It is detonated by a military electric or nonelectric blasting cap. Watersoaked detonating cord will detonate if initiated from a dry end. Like other high explosives, it is subject to sympathetic detonation, Detonating cord is issued in spools in 50-, 100-, 500-, and 1,000-foot lengths. Detonating cord with a pilofilm cover is issued in 500-foot spools only. For information on knots used for connecting detonating cord, see paragraph 50*b* and *c*. Three types of detonating cord—I, II, and IV—are used in military demolitions on land and under water.

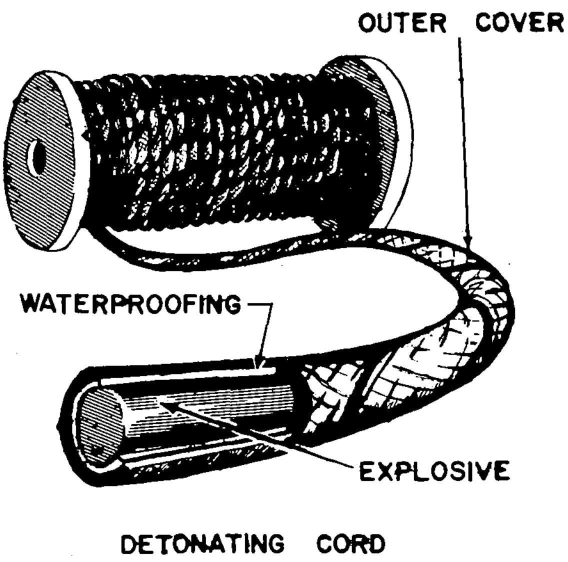


Figure 43. Types I and II detonating cord (diameters different).

b. Types I and II Detonating Cord (fig. 43). These standard B types consist of an explosive core of PETN enclosed in a braided seamless cotton tube. On the outside of this tube is a layer of asphalt covered by a layer of rayon with a wax gum composition finish. Type II has a slightly larger diameter than type I, as it has an extra layer of cotton covering that increases its tensile strength to approximately 150 pounds.

c. Type IV, Plastic-Reinforced Detonating Cord. This standard A cord is similar to that described in *b* above, except for the special plastic covering designed for vigorous use and severe weather (fig. 44). This covering increases the cord's tensile strength from 150 pounds to 250 pounds; it also makes the cord more stable in high temperatures and decreases the possibility that the wrapper may lose its waterproof qualities when handled.

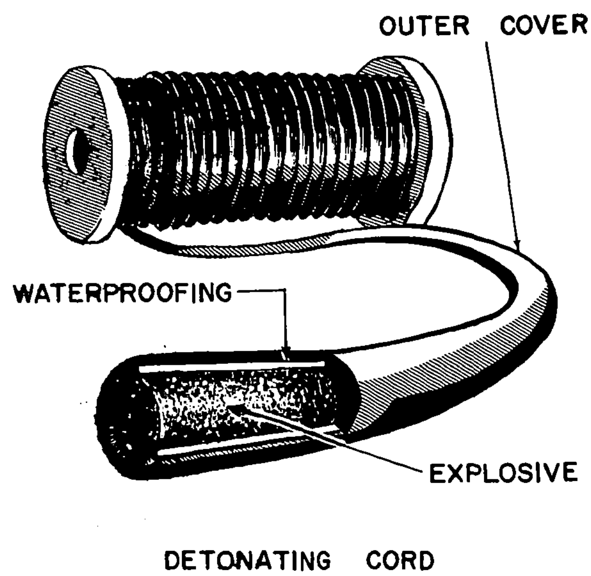


Figure 44. Type IV detonating cord.

50. Assemblies and Connections

a. Detonating Assemblies.

(1) *Nonelectric.* This detonating assembly consists of a length of detonating cord (approximately 2 feet), nonelectric blasting cap, a length of time fuse, and a fuse lighter. The blasting cap is crimped to the time fuse and then fastened to the detonating cord (fig. 45). The fuse lighter is then fastened to the time fuse. The length of time fuse depends on the time required

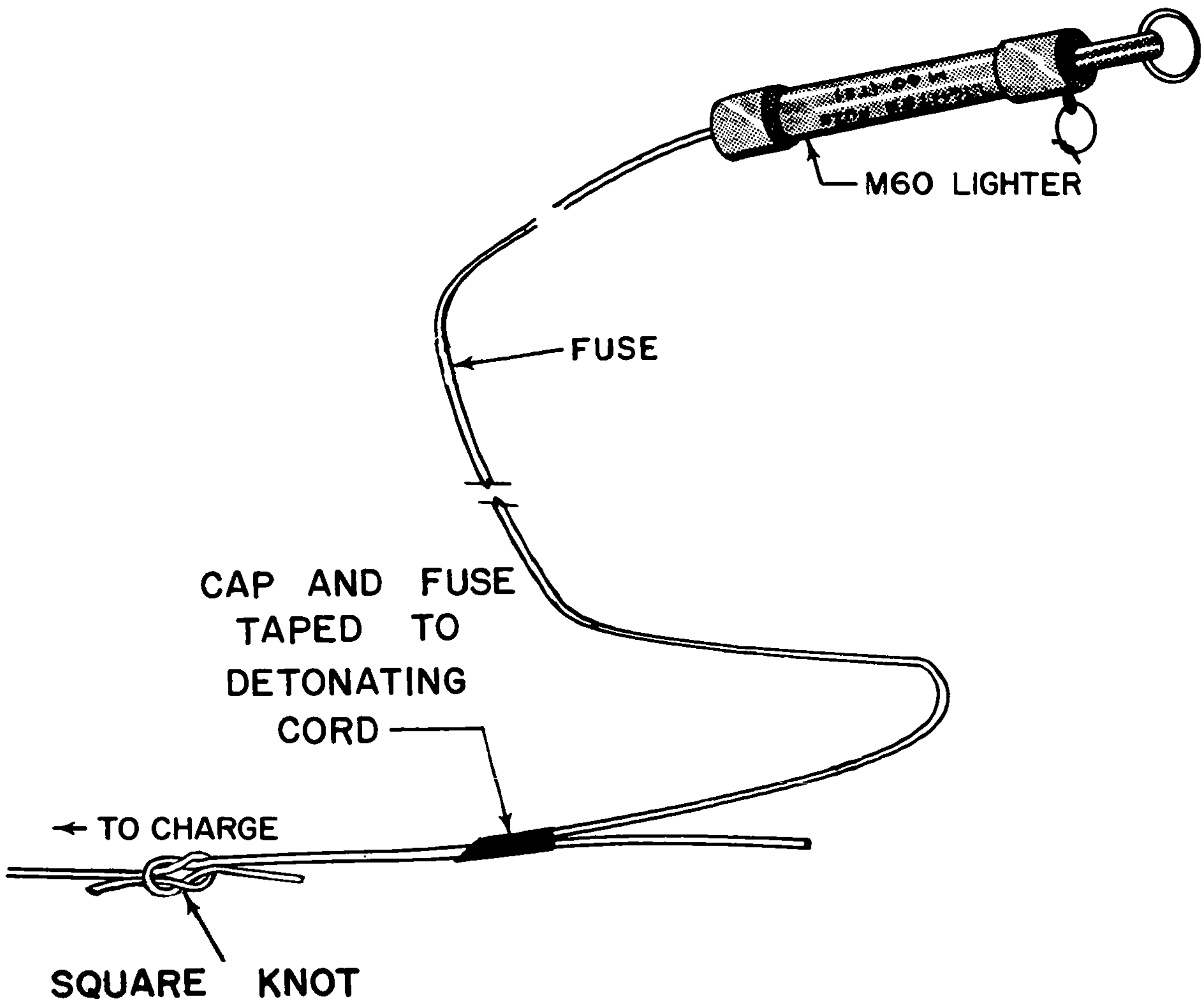


Figure 45. Nonelectric detonating assembly attached to main line.

for the soldier to reach safety after lighting the fuse.

(2) *Electric.* The electric detonating assembly is a length of detonating cord (approximately 2 feet) with an electric blasting cap attached.

(3) *Attachment of assembly to system.* The free end of the detonating cord is fastened to the main line by a clip or a square knot as shown in figure 44.

(4) *Uses.* Detonating assemblies can be used in most charges but are the best primers for pole charges.

(5) *Advantages.* There are two advantages to be gained by the use of these primers—they may be made up in advance, thus saving time in the field, which is a great advantage when time is a critical factor, and they may be fastened to the main line without the danger of premature detonation of the entire system while charges are being prepared.

b. Detonating Cord Connections. A detonating cord clip or a square knot pulled tight is used to splice the ends of the detonating cord. At least a 6-inch length should be left free at both sides of the knot (fig. 46). The fabric covering of the detonating cord must not be removed, nor the knot placed in water or in the ground unless the charge is to be fired immediately.

c. Branch Line Connections.

(1) *Method.* A branch line is fastened to a main line by means of a clip, previously described in paragraph 48*b*, or a girth hitch (fig. 47). The loose ends of the girth hitch should be on the opposite side of the branch line from the initiating point on the main. A girth hitch will hold only on

detonating cord that has a fabric covering and not on detonating cord that has a plastic covering or on reinforced detonating cord. On plastic-covered detonating cord, the branch line connection knot is a girth hitch with an extra turn. The angle formed by the branch line and the cap end of the main line should not be less than 90° from the direction from which the blast is coming; at a smaller angle, the branch line may be blown off the main line without being detonated. At least 6 inches of the running end of the branch line is left free beyond the tie. If sufficient detonating cord is available, a ring main (fig. 48) may be used in which the main line is brought back and attached to itself with a girth hitch. This makes detonation of all charges more positive because the detonating wave approaches the branch lines from both directions and the charges will be detonated even when there is a break in the main line. Branch lines coming from a ring main should be at a 90° angle. Any number of branch lines may be connected to the main line, but a branch line is never connected at a point where the main line is spliced.

(2) *Precautions.* In making branch line connections, it is necessary to insure that detonating cords do not touch in places where they cross. If crossing cords touch, they may cut each other and possibly destroy the firing system.

51. Priming TNT, M2 Demolition Block, and Dynamite

a. The priming of TNT and M2 demolition blocks with detonating cord, with or without threaded cap wells, is accomplished in the manner described in paragraphs 29*a*(2) and 48*a*(1) and (2), which also include alternate methods (figs. 39 and 40).

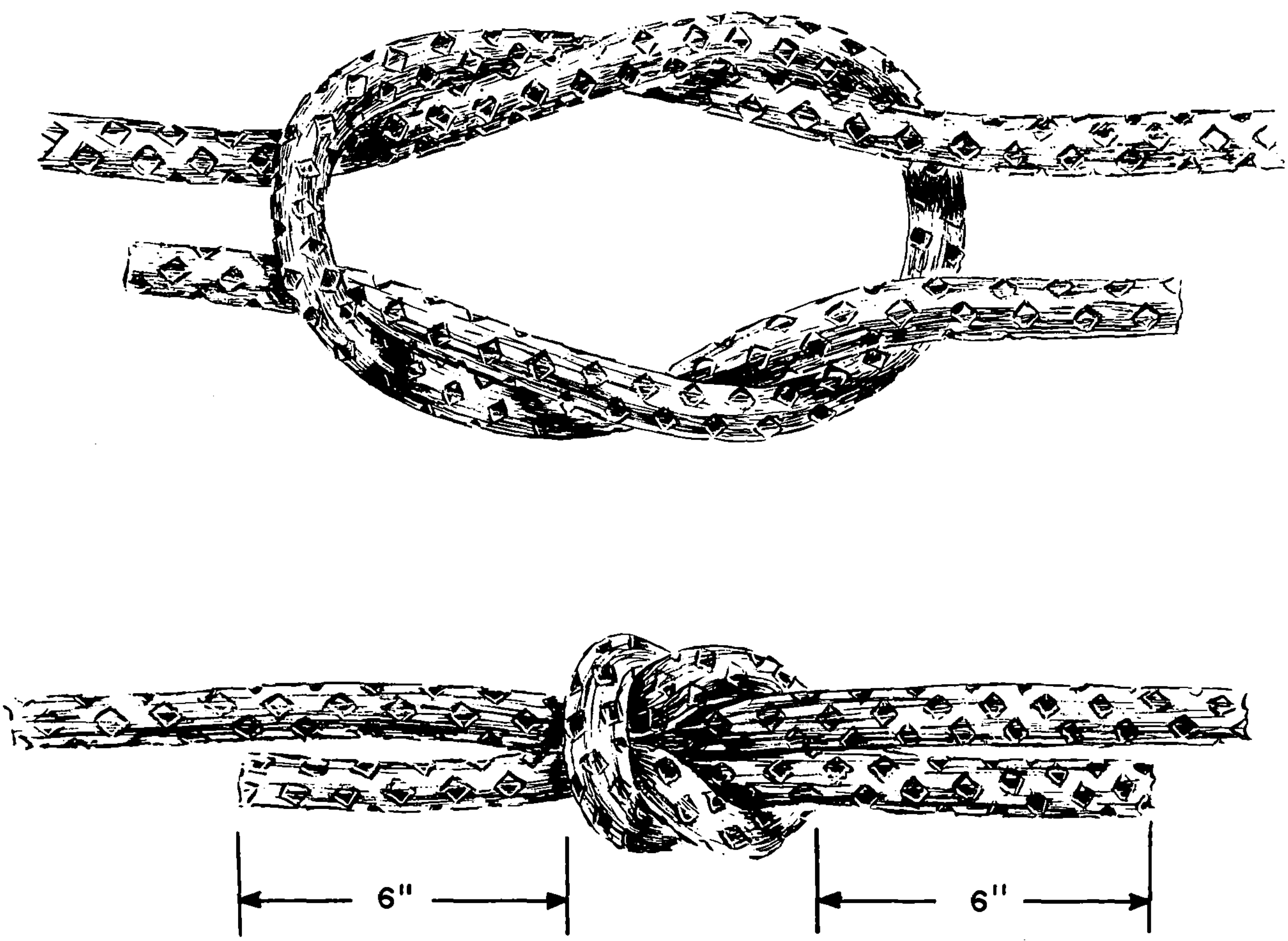


Figure 46. Square knot detonating cord connections.

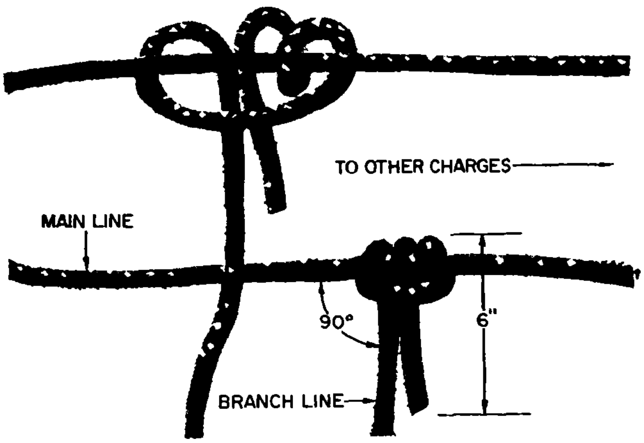


Figure 47 Girth hitch detonating cord connection of branch line to main line.

b. Dynamite is primed for use primarily in boreholes, ditching, or stumps by lacing the detonating cord through it. This is done by punching four equally spaced holes through the dynamite cartridge and running the detonating cord back and forth through them (fig. 38).

52. Priming M1 Chain Demolition Blocks

The M1 chain demolition block has detonating cord running lengthwise through the individual blocks. If an additional length of detonating cord is required, it is connected to the detonating cord of the chain with a clip or square knot. If the cord running through the blocks is cut too closely to the end block to permit such a connection, the extra length of detonating cord may be fastened by a clove hitch with two extra turns near the end of the block over the booster.

53. Priming Plastic Explosives (Compositions C3 and C4)

Compositions C3 and C4 are primed with detonating cord, as follows:

a. Take a 10-inch bight at the end of the detonating cord and tie an overhand knot (1, 2, fig. 49).

b. Mold the explosive around the knot, leaving at least ½ inch of explosive on all sides and at least 1 inch on each end (3, 4, fig. 49).

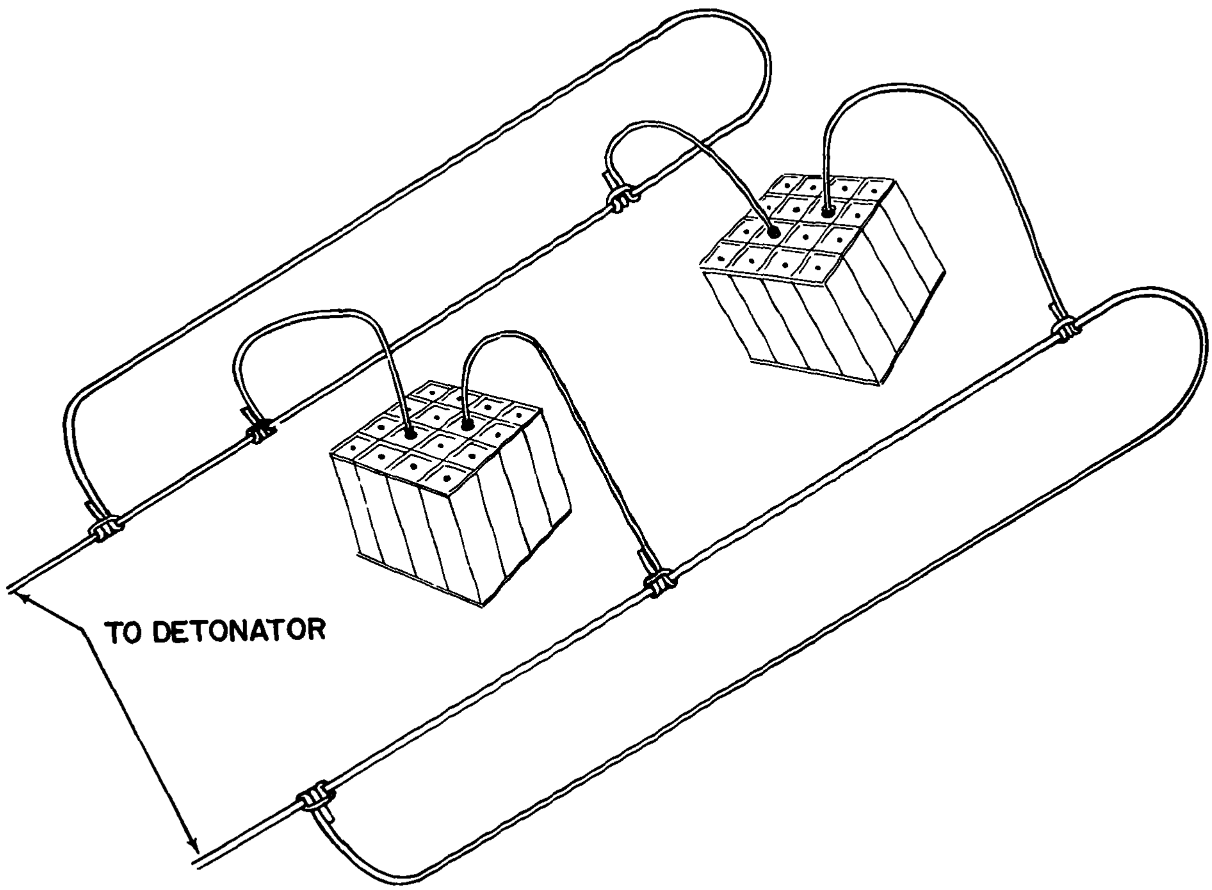
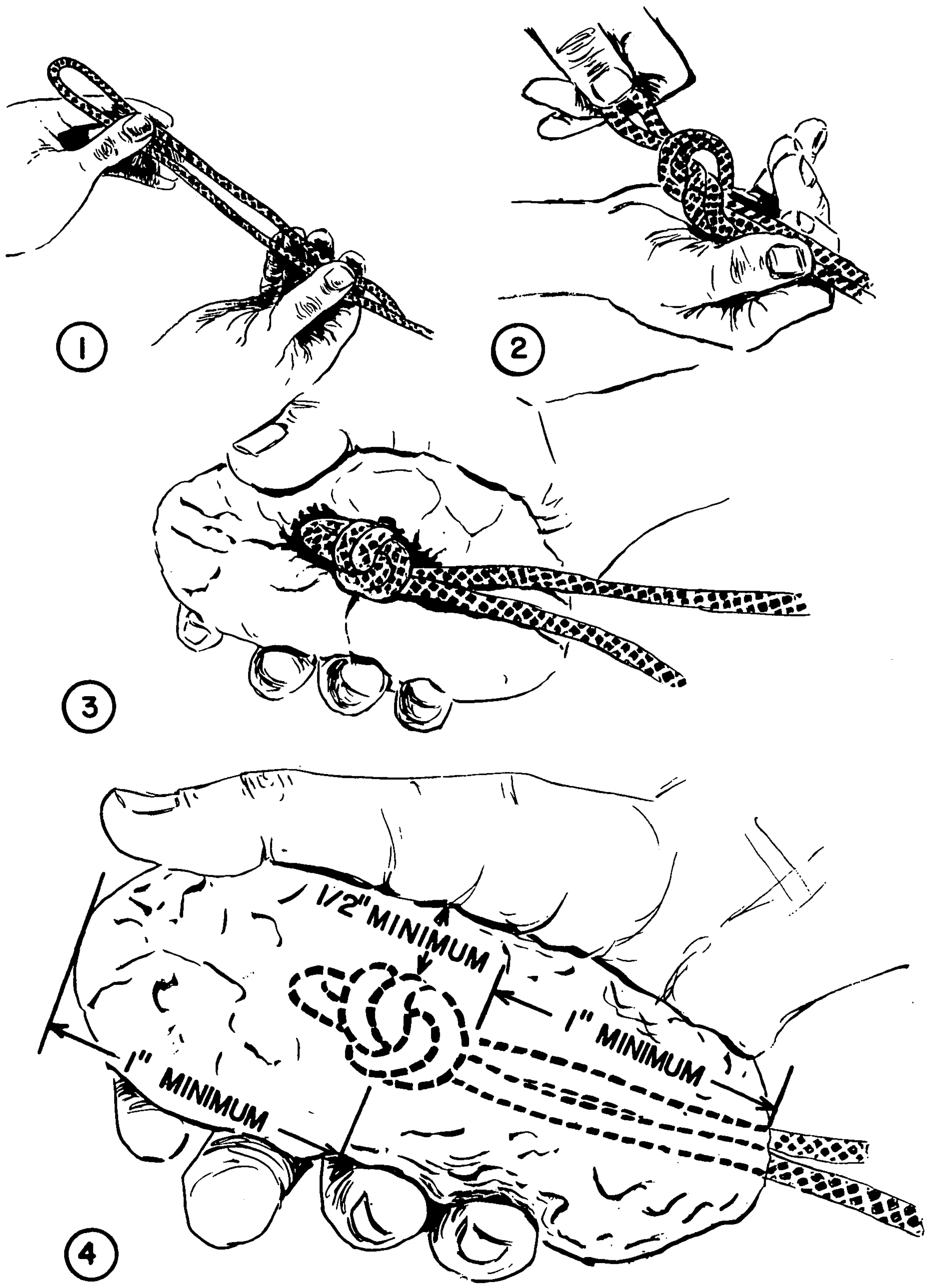


Figure 48. Nonelectric dual firing system using two ring mains.



1 Loop 2 Tying knot 3 Placing knot in charge 4 Primed charge

Figure 49. Priming plastic explosive with detonating cord.

Figure 50. Ammonium nitrate primed with detonating cord.

54. Priming Cratering Charges

The ammonium nitrate and nitramon cratering charges are primed by passing the detonating cord through the tunnel on one side of the can and tying an overhand knot 6 inches from the end of the cord (fig. 50).

55. Priming Pole Charges

Best results are obtained from pole charges if they are primed with detonating cord assemblies. The method of priming is shown in figure 51.

56. Handling Detonating Cord Misfires

a. Failure of Nonelectric Blasting Cap. If a nonelectric blasting cap initiator attached to detonating cord fails to function, delay the investigation for at least 30 minutes. Then cut the detonating cord main line between the blasting cap and the charge, and fasten a new blasting cap initiator on the detonating cord.

b. Failure of Electric Blasting Cap. If an exposed electric blasting cap fastened to detonating cord fails to fire, disconnect the blasting circuit immediately and investigate. Test the blasting circuit for any breaks or short circuits, and if necessary, remove the original blasting cap and fasten a new one in its place.

c. Failure of Detonating Cord. If detonating cord fails to function at the explosion of an exposed electric or nonelectric blasting cap, investigate immediately. Attach a new blasting cap to the detonating cord, taking care to fasten it properly.

d. Failure of Branch Line. If the detonating cord main line detonates but a branch line fails, fasten a blasting cap to the branch line and fire it separately.

e. Failure of Charge to Explode. If the detonating cord leading to a charge detonates, but the charge fails to explode, delay investigation until it is certain that the charge is not burning. If the charge is intact, insert a new primer. If the charge is scattered by the detonation of the original detonating cord, reassemble as much of the original charge as possible, place a new charge when necessary, and insert a new primer. Make every attempt possible to recover all unexploded explosives scattered by misfire, particularly in training exercises.

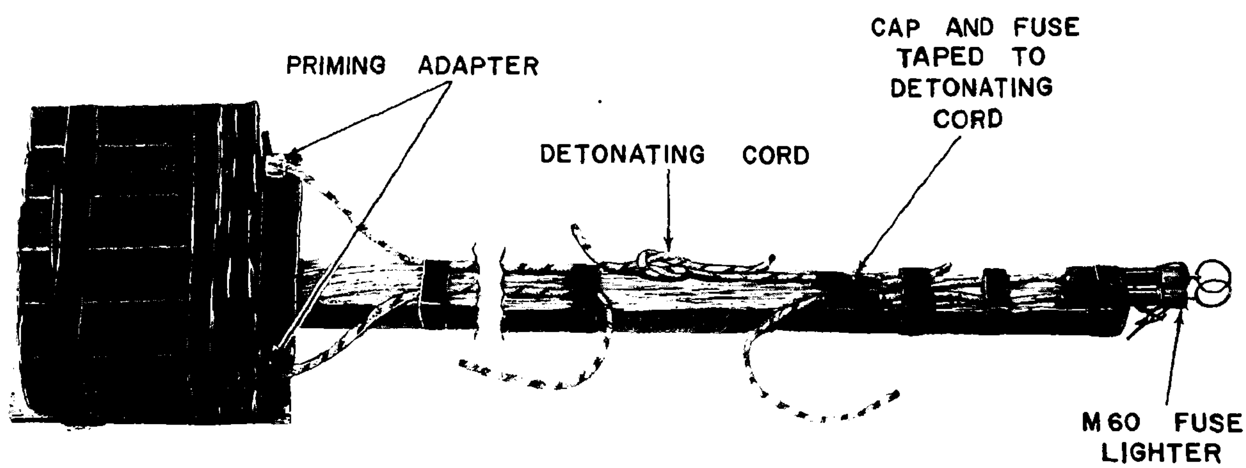


Figure 51. Pole charge primed with detonating cord.

57. Reduction of Misfire Risks

a. The use of a dual firing system greatly increases the probability of successful firing. In combat, misfires may cause the loss of battles; in training, they cause the loss of valuable time and endanger the lives of those that investigate them. It is necessary to take every possible precaution to avoid misfires of demolition charges.

b. The failure of firing circuits is most frequently the cause of demolition misfires. Thus a dual firing system should be used whenever time and materials are available. It may consist of two electric circuits, two nonelectric circuits, or one electric and one nonelectric circuit. The circuits must be entirely independent of each other; and at least two blocks of explosive in each charge must be primed.

58. Nonelectric Dual Firing System

This consists of two independent nonelectric systems for firing a single charge or set of charges. If two or more charges are to be fired simultaneously, two detonating cord ring mains are laid out, and a branch line from each charge is tied into each ring main. Figure 52 shows the layout for nonelectric dual firing systems.

59. Electric Dual Firing System

This dual firing system consists of two independent electric circuits, each with an electric blasting cap

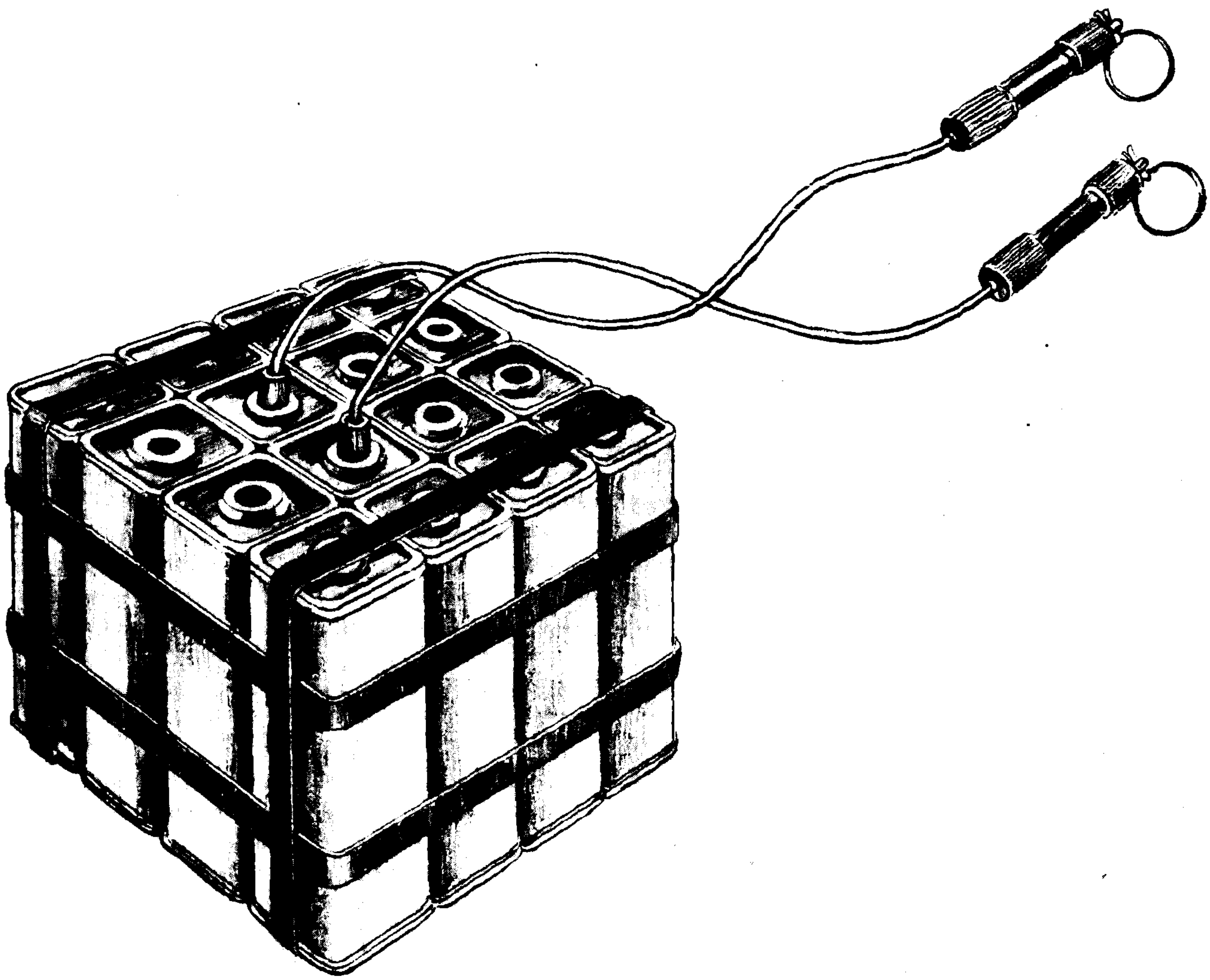


Figure 52. Nonelectric dual firing system for a single charge.

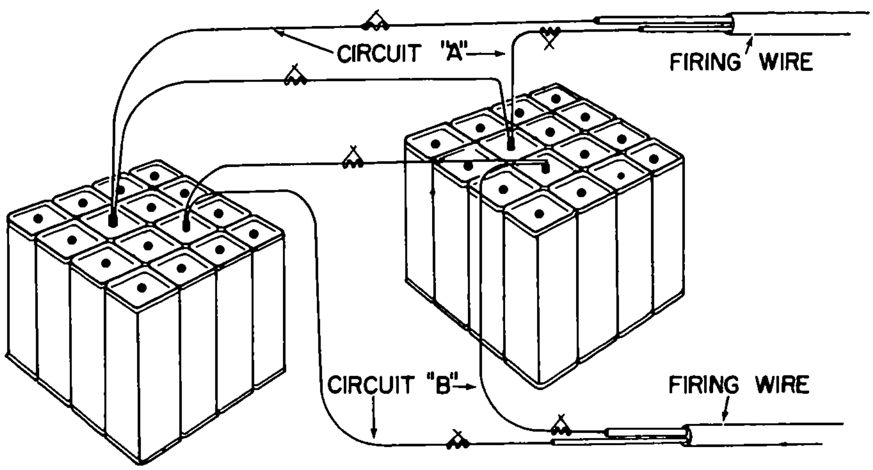


Figure 53. Electric dual firing system.

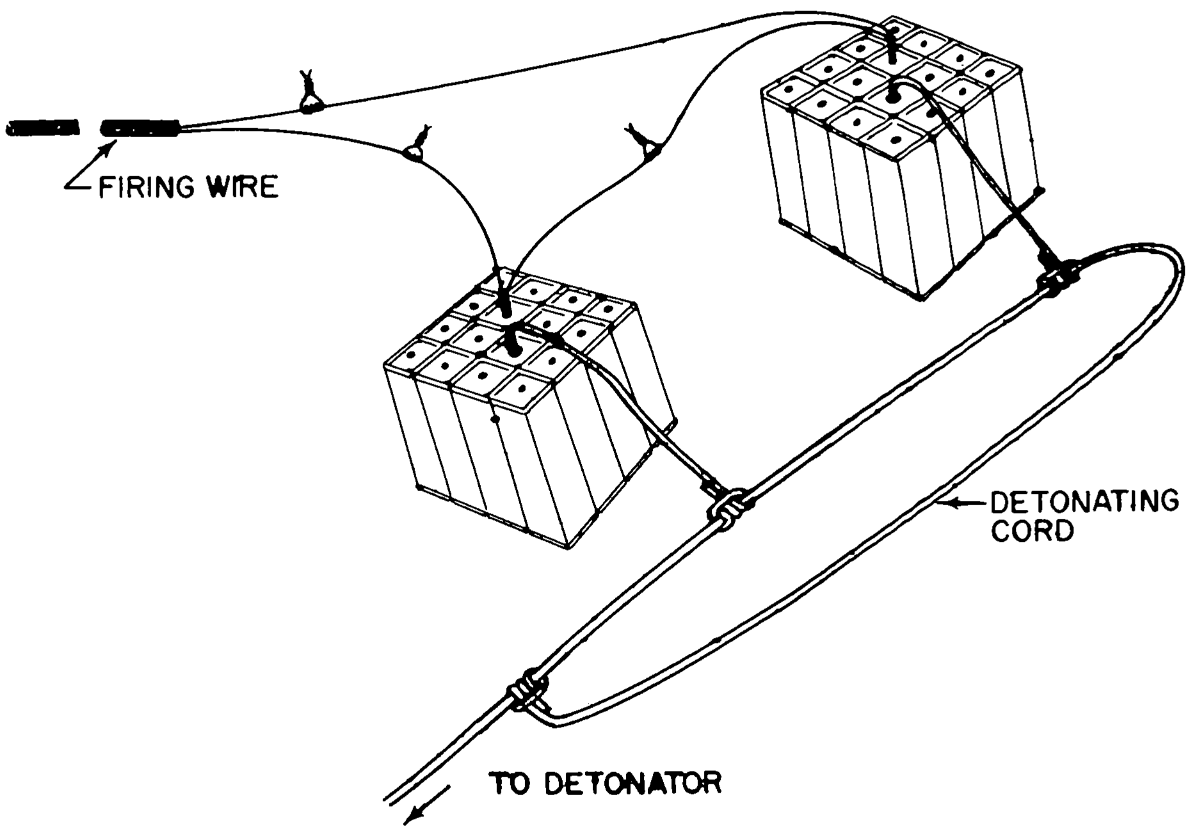


Figure 54. Combination dual firing system.

in each charge, so that the firing of either circuit will detonate all charges. Thus, each charge must have two electric primers. The correct layout is shown in figure 53. The firing wires of the two circuits should be kept separated so that both will not be cut by a single bullet or a single shell fragment. The firing points also should be at two separate locations.

60. Combination Dual Firing System

a. The combination dual firing system requires an electric and a nonelectric firing circuit (fig. 54). Each charge has an electric and a nonelectric primer made with a blasting cap or detonating cord. Both the electric and nonelectric circuits must be entirely independent of each other. The nonelectric system should be fired first, however.

b. All the above systems may consist of two detonating cord ring mains both fired electrically or nonelectrically or fired by an electric or nonelectric combination.

Section V. DEMOLITION SETS

61. Types of Sets

Demolition sets are an assembly of demolition explosive items, accessories, and tools for various demolition jobs. They are placed in special containers with carrying attachments. They are issued to engineers, infantry, and other units according to tables of equipment. Sets issued to engineer units have accessories for electric and nonelectric firing. Those issued to other units are for nonelectric firing, although supplementary electric firing equipment is sometimes included.

62. Electric and Nonelectric Demolition Set

The electric and nonelectric demolition equipment set consists of TNT and M5A1 (Composition C4) demolition blocks and accessories for electric and nonelectric priming and firing. The set is carried in the engineer platoon demolition chest. The components are shown in figure 55.

63. Nonelectric Demolition Set

The nonelectric demolition equipment set consists of M5A1 (Composition C4) demolition blocks and accessories for nonelectric priming. The set is carried in a canvas haversack. The components are shown in figure 56.

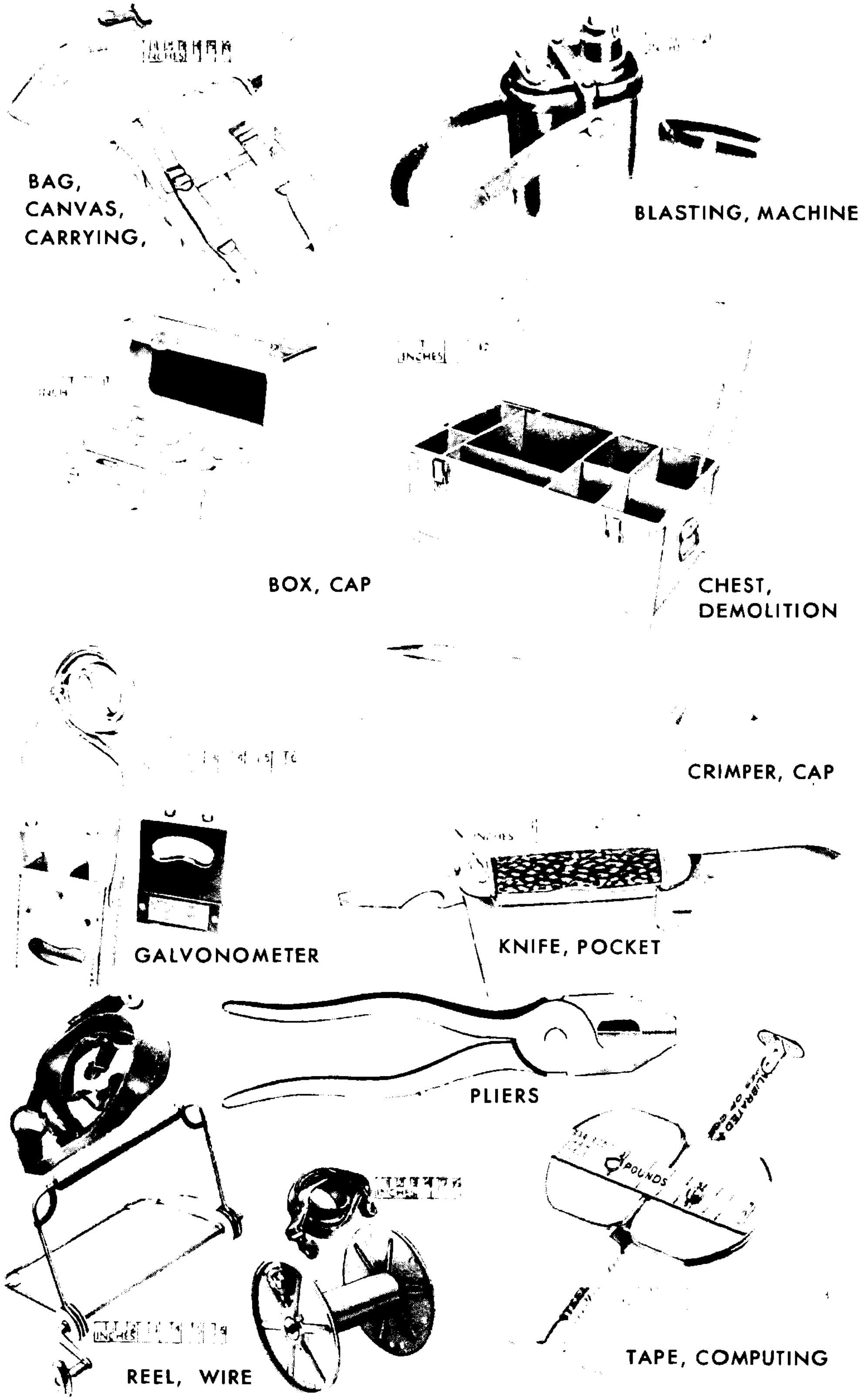


Figure 55. Demolition equipment set, electric and nonelectric.

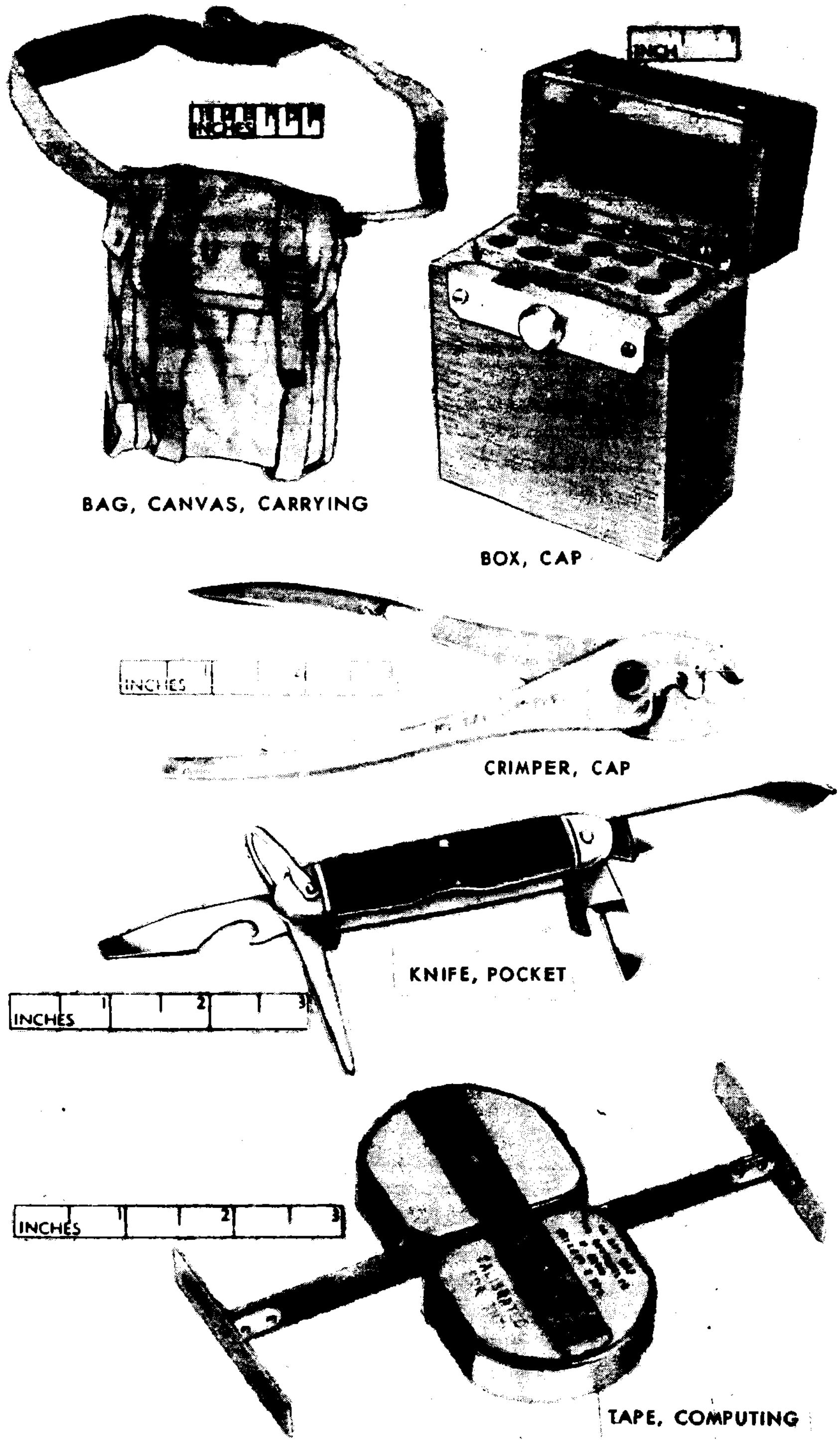


Figure 56. Demolition equipment set, nonelectric.

CHAPTER 3
CALCULATION AND PLACEMENT OF CHARGES

Section I. REQUIREMENTS AND PROCEDURES

64. Critical Factors in Demolitions

The critical factors in demolitions are selection of the explosive and the size, placement, and confinement of the charge. These factors apply generally to all types of charges—timber-cutting, steel-cutting, pressure, breaching, and cratering. The explosive must be suited to the demolition task, such as cutting or breaching, and the charge must be of the right size and correctly placed and confined for the required destruction.

a. Selection of Explosive. The selection of the explosive with the proper characteristics is important; however, under conditions of short supply, it will be necessary to substitute one explosive for another. The problem is then one of adjustment of size, method of detonation, and confinement.

b. Size of Charge. This is computed by means of formulas or taken from tables or the computing tape.

c. Placement of Charge. The charge must be fastened, supported, or buried at the proper place or to the proper depth in order to give satisfactory results. The charge must be located at the proper point to obtain the optimum destructive effect. This is usually not complete destruction of the target, but the rendering of it unusable, or the creating of an obstacle to impede enemy movement.

d. Confinement. As the detonation of an explosive produces pressure in all directions, a charge sealed tightly inside an object or fixed to an object and covered (tamped) exerts force on the material around it and produces under such conditions the maximum destructive effect.

65. Selection of Explosive

Explosives are selected in accordance with the requirements of a particular job. Explosives used by the Army and their application to demolition projects are listed in table IV.

66. Size of Charge

The amount of explosive used in a demolition project is determined by formula calculation, and by means of computing tape or tables.

a. Formulas. Formulas for computing specific charges—timber and steel cutting, breaching, and so on—are given in succeeding sections of this chapter. In the formulas (for example, $P=D^2$), the value of P is the amount of TNT (in pounds) required for an external charge. If other explosives are used, the value of P must be substituted according to the strength of these other explosives in relation to TNT (table IV, col. 4) but only when the external charges are computed from these formulas. The substitution is computed by dividing the P value (TNT) by the relative strength factor for the explosive to be used. Steel and timber charges, usually small, should be computed by formula when possible.

Note. When charges are calculated by "rule of thumb," do not apply the relative effectiveness factor.

b. Computing Tape. The charge computing demolition tape (fig. 56), provides a rapid method of calculating the weight of TNT (in pounds) needed to carry on a demolition project. It combines in an abbreviated form most of the formulas and tables in paragraphs below. The assembly consists of two 6-foot flexible steel spring retractable tapes in joined metal housings. The two tapes have a total of five sets of markings. A rigid embossed scale is mounted on one side of the housing. The scales are—

(1) *First tape (breaching and pressure scales).* The upper side of this tape indicates the pounds of TNT required to breach concrete, masonry, timber, or earthen walls, making allowances for the tamping and placement of charges. The weight is read directly to the right of the mark that indicates the thickness of the wall or

Table IV. Characteristics of Explosives

Name	Principal use	Smallest cap required for detonation	Velocity of detonation (ft per sec)	Relative effectiveness as external charge (TNT=1.00)	Intensity of poisonous fumes	Water resistance
TNT	Main charge, booster charge, cutting and breaching charge, and general use in combat areas.	Military blasting cap, electric or nonelectric.	21,000	1.00	Dangerous	Excellent.
Tetrytol			23,000	1.20	Dangerous	Excellent.
Composition C3			26,000	1.34	Dangerous	Good.
Composition C4			26,000	1.34	Slight	Excellent.
Ammonium Nitrate (Military cratering charge).	Cratering and ditching (in container).		11,000	0.42	Dangerous	Good, (f container is not ruptured).
Military Dynamite M1	Land clearing, quarry and rock cuts, and general use.		20,000	0.92	Dangerous	Good.
Straight Dynamite (Commercial) 40% 50% 60%	Land clearing, quarry and rock cuts, and general use.	No. 6 commercial cap, electric or nonelectric.	15,000	0.65	N/A	Good, (if fired within 24 hrs).
Ammonia Dynamite (Commercial) 40% 50% 60%	Land clearing, cratering, quarrying, and general use in rear areas.	No. 6 commercial cap, electric or nonelectric.	9,000 11,000 12,000	0.41 0.46 0.53	Dangerous	Poor.
Gelatin Dynamite 40% 50% 60%			8,000 9,000 16,000	0.42 0.47 0.76	Slight	Good.
PETN	Detonating cord	No. 8 commercial cap*	21,000	N/A	Slight	Good.
	Blasting caps	N/A	N/A	N/A	N/A	N/A
TETRYL	Booster charge	Military blasting cap*	23,400	1.25	Dangerous	Excellent.
	Blasting caps	N/A	N/A	N/A	N/A	N/A
Composition B	Bangalore torpedo and shaped charges.	Military blasting cap, electric or nonelectric.	25,500	1.35	Dangerous	Excellent.
Black Powder	Time fuse	N/A	N/A	N/A	Dangerous	Poor.
RDX	M6 and M7 blasting caps.	N/A	N/A	N/A	N/A	N/A

*Electric or nonelectric.

obstacle. The lower side of the tape has information on breaching concrete beams, roadways, and bridge spans. It is used to measure the thickness of the target or element. The weight of the charge may be read directly from the tape without consideration of the actual dimensions of the target.

(2) *Second tape (steel and timber-cutting scales)*. This tape contains the requirements for cutting steel and timber construction materials. One side shows the weight of TNT needed for cutting timber for both internal and external placement. The reverse side has a rule for the calculation of the cross-sectional area of steel members and also the formulas for cutting.

(3) *Bar and rod-cutting scale*. The small scale on the exterior of the case is used for making calculations for the cutting of rods, bars, chains, and cables. The number of pounds of TNT needed for cutting is read directly from the scale.

c. Demolition Card. This pocket sized card (GTA 5–14) gives in tabulated form, data for the calculation of pressure. timber-cutting, steel cutting, breaching, and cratering charges.

67. Placement of Charge

a. Proper Placing. Charges are placed properly for maximum effectiveness. For cratering, they are placed in holes in the ground; on stone or concrete abutments, they are placed in the proper spot with or without tamping, depending on the time and materials available; on timber they may be tied on the outside or placed in boreholes, whichever is the most practical.

b. Placement Accessories. Charges are fastened to the target by wire, adhesive compound, friction tape, or string or propped against the target by means of a wooden or metal frame made of scrap or other available materials; or placed in boreholes. Special accessories are issued for this purpose—adhesive compound, the rivet-punching powder-actuated driver, earth auger, and pneumatic tools.

(1) *Adhesive compound*. Adhesive compound is a sticky putty-like substance used for attaching charges to vertical or overhead flat surfaces. It is also excellent for holding charges while tying them in place and under some conditions for holding them without tying. Charges may be held in place by adhesive compound for periods ranging from several minutes to several days, depending on the size and shape of the charge and the surface to which it is attached. Adhesive compound will hold a single thickness of explosive blocks to clean wood, steel, or concrete for several days, but will not adhere satisfactorily to dirty, wet, or oily surfaces. As it is softened by water, it is useless when wet. At subzero temperatures it becomes stiff and hard and thus loses its adhesive quality.

(2) *Rivet-punching powder-actuated driver*.

(*a*) *Description*. This is a riveting machine powered by the gases generated by a fired cartridge (fig. 57). It is hand-operated, air-cooled, and feeds from a magazine with a 10-cartridge fastener unit capacity. It operates effectively under water. The waterproofed fastener unit has a sharp point and a coarsely knurled body to provide maximum holding power in light steel, softer metals, concrete, and heavy wood. The sabots an annular threaded unit, screws on the rear of the fastener to guide it in ejection, act as a stop-shoulder, and provides additional bearing on the penetrated material. The cartridge case is a specially wadded caliber .38 steel case A manual device is provided for cocking the driver under water.

(*b*) *Operation*. The firing of the cartridge propels the fastener and sabot into the target. The fastener acts as a rivet for attaching charges to steel, concrete, or wooden targets. The device is especially useful where working space is severely limited and for underwater work. (*Do not fire the driver into explosive or immediately adjacent to exposed explosive.*)

(3) *Earth auger*. Two types of earth augers, hand-operated and motorized, are used for boring holes for the placement of cratering charges and bridge-abutment demolition charges. Boring speed depends on the type and consistency of the soil, being most rapid in light earth or loam. Earth augers cannot be used satisfactorily in soil containing large rocks.

(*a*) *Hand-operated*. The 10-inch post hole auger is capable of boring a hole large enough for the 40-pound ammonium nitrate cratering charge and other

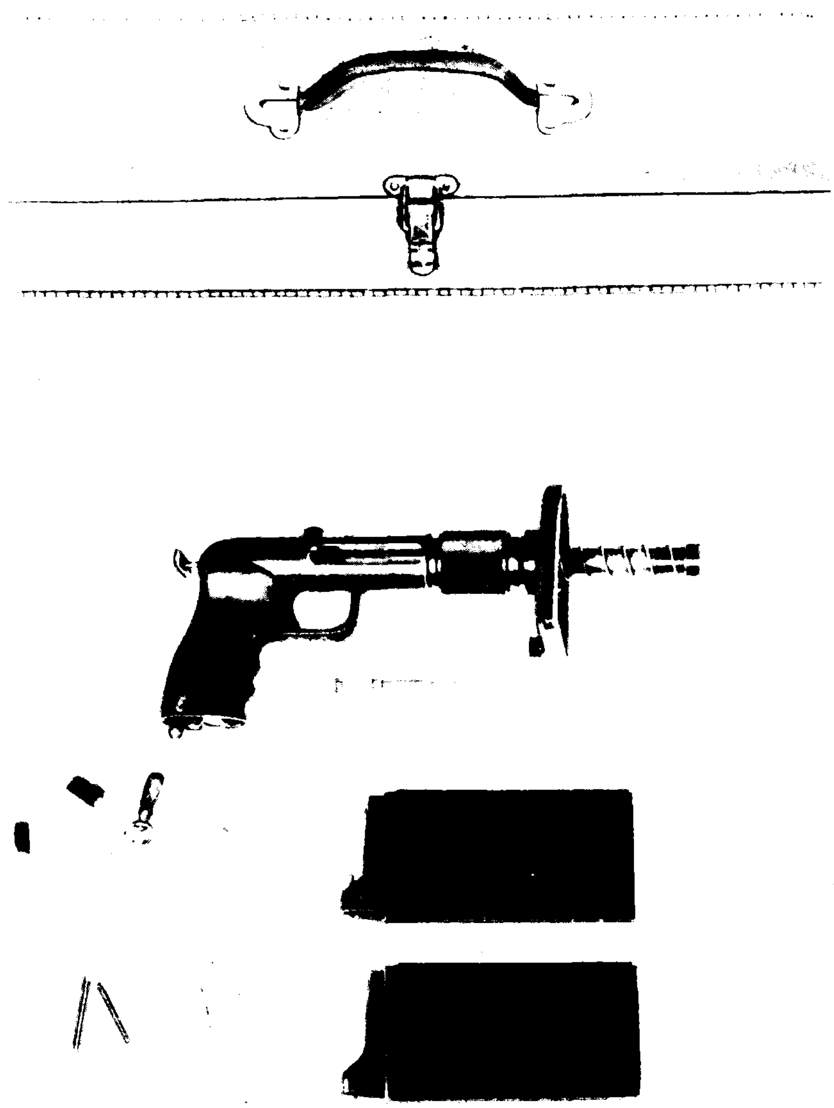


Figure 57. Rivet-punching powder-actuated driver.

charges of equal size. The telescoping handle permits drilling as deep as 8 feet.

(*b*) *Motorized.* Motorized earth augers drill holes 8, 12, 16, or 20 inches in diameter to depths up to 8 feet.

(4) *Pneumatic tools.* These are the rock drill, pavement breaker, and wood-boring machine. The *rock drill* bores holes up to 2 inches in diameter on rock, concrete, or masonry for the placement of internal charges. The *pavement breaker* is used to shatter the hard surface of roads before drilling boreholes with an auger for cratering charges. The *woodboring machine* drills boreholes in wood for the placement of internal charges.

68. Confinement of Charge

The detonation of an explosive produces pressure in all directions. If the charge is not completely sealed in or confined or if the material surrounding the explosive is not equally strong on all sides, the explosive force breaks through the weakest spot and part of the destructive effect is lost. To conserve as much of this explosive force as possible, material is packed around the charge as is done with an external charge in bridge demolitions. This material is called *tamping material* or *tamping*, and the process, *tamping*. On the other hand, an internal charge (one placed in the target to be destroyed) is confined by packing material in the borehole on top of the charge as is done in cratering. This is called *stem-*

ming. Explosive charges are generally tamped and stemmed as described below.

a. Internal Charges. These are confined by tightly packing sand, wet clay, or other material (stemming) into the opening of thc hole containing the charge. This is tamped and packed against the explosive to fill the hole all the way to the collar. In drill holes, tamping should not begin until the explosive is covered by at least one foot of stemming. Light materials are not acceptable, as they are apt to blow out of the borehole and cause incomplete destruction. Neither are flammable materials, which may ignite, like paper, sawdust, and sacking.

b. External Charges. These are tamped by covering them with tightly packed sand, clay, or other dense material. Tamping may be in sandbags or loose. For maximum effectiveness, the thickness of the tamping should at least equal the breaching radius. Small breaching charges on horizontal surfaces are sometimes tamped by packing several inches of wet clay or mud around them. In quarry operations, this process is called mudcapping.

Section II. TIMBER-CUTTING CHARGES

69. Critical Factors

In timber cutting, the selection, calculation, placement, and confinement of the explosive charge are all evaluated, but in this type of charge the determination of the correct size is relatively difficult. This is because of the varying densities of the different types of wood.

70. Selection of Explosive

For untamped external charges, block explosive is adequate, as it is easily tied or fastened in place and the size is calculated by formula based on its characteristics. Plastic explosive is also satisfactory, but the amount must be calculated by a modification of the formula given. For tamped internal charges in boreholes, dynamite is generally used, as it is the most convenient to place because of the size of the cartridge and is adequate because of tamping.

71. Size of Charge

It is impractical to attempt to cut all kinds of timber with charges of a size calculated from a single formula. There is too much variation between different kinds of timber from locality to locality. Accordingly, test shots must be made to determine the size of the charge to cut a specific type of timber. Formulas for the calculation of these shots are provided for untamped external charges, felling trees for an abatis, and for tamped internal charges. They are as follows:

a. Formula for Untamped External Charges. For cutting trees, piles, posts, beams, or other timber members with an untamped external charge, the following formula is used for the test shot for either round or rectangular members:

$P = \frac{D^2}{40}$ where P = pounds of TNT required,

D = least diameter of the timber in inches or the least dimension of dressed timber, and

40 = constant

Adjustment for explosives other than TNT will be made using the relative effectiveness factor which pertains to the particular explosive being used. The amount of explosive required to cut a round timber 30 inches in diameter using an untamped external charge is determined as follows:

$$P = \frac{D^2}{40}$$

D = 30 inches

$$P = \frac{(30)^2}{40} = 22.5 \text{ pounds of TNT.}$$

b. Formula for Partially Cutting Trees to Create an Obstacle or Abatis. When cutting trees and leaving them attached to the stumps to create an obstacle, the formula, $P = \frac{D^2}{50}$ is used to compute the amount of TNT required for the test shot. The result of the test shot will determine the need for increasing or decreasing the amount of explosive required for subsequent shots.

c. Formula for Tamped Internal Charges. Tamped internal cutting charges may be calculated by the following formula:

$$P = \frac{D^2}{250}$$

Where P = pounds of explosive required,

D = diameter or least dimension of dressed timber, in inches, and

250 = constant.

The amount of explosive required to cut a 15-inch diameter tree, using tamped internal charges, is determined as follows:

Figure 58. External timber-cutting charge.

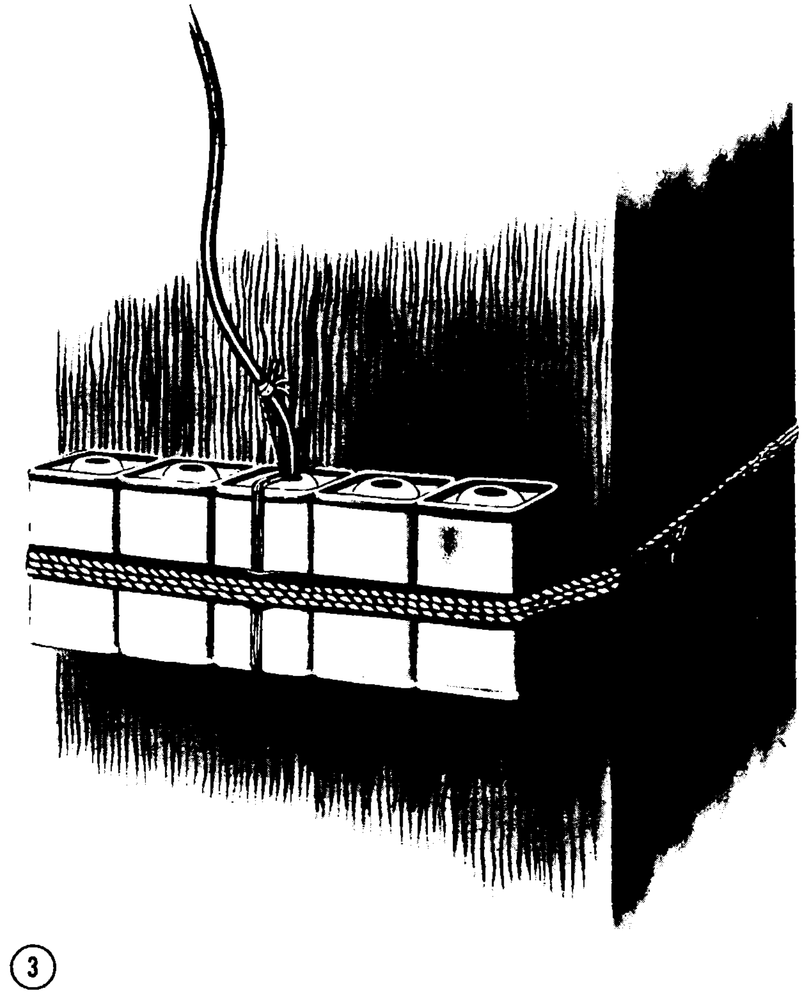


Figure 59. External cutting charge on rectangular timber.

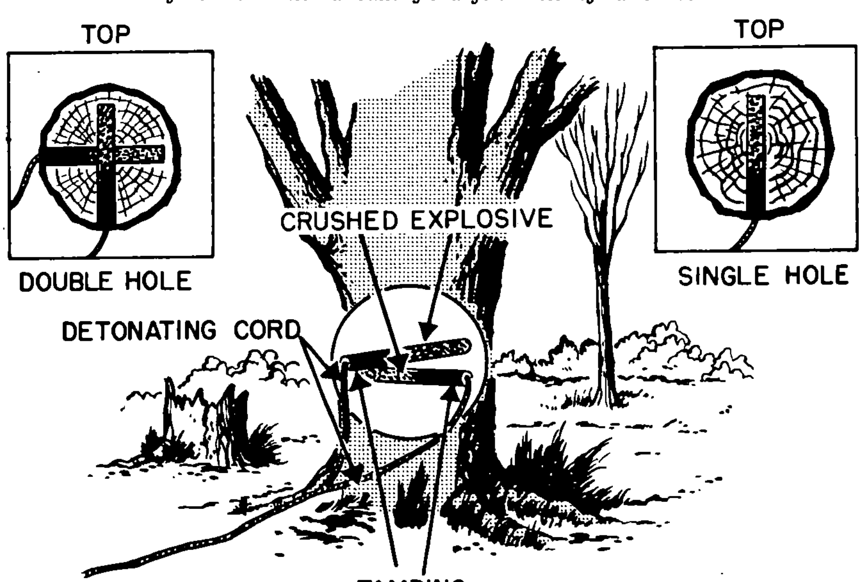


Figure 60. Internal tree-cutting charge.

$$P=\frac{D^2}{250}$$

$$P=\frac{15^2}{250}=\frac{225}{250}=0.90 \text{ or 1 pound.}$$

72. Placement of Charge

a. External Charges. External charges are placed as close as possible to the surface of the timber regardless of the kind of cut desired (fig. 58). Frequently it is desirable to notch the tree to hold the explosive in place. If the tree or timber is not round and the direction of fall is of no concern, the explosive is placed on the widest face so that the cut will be through the least thickness. The tree will fall toward the side where the explosive is placed, unless influenced by lean or wind. Charges on rectangular or square dressed timber are placed as shown in figure 59.

b. Internal Charges. These are placed in boreholes parallel with the greatest dimension of cross section and tightly tamped with moist clay or sand. If the charge is too large to be placed in one borehole, bore two close together. On round timber, bore the two holes at approximate right angles to each other (fig. 60). Both boreholes are primed and the charges are fired simultaneously.

c. Abatis. Charges for making obstacles are placed the same as those in *a* above, except that they are placed approximately 5 feet above ground level. To make the obstacles more difficult to remove, they should be mined, boobytrapped. and covered by fire.

73. Confinement of Charge

External charges are not tamped or confined but merely fastened to the target; internal charges are tamped with moist sand or clay or some other suitable material which conserves much of the explosive power.

Section III. STEEL-CUTTING CHARGES

74. Critical Factors

In the preparation of steel-cutting charges, the factors of type, size, and placement of explosive are important in successful operations. The confinement of the charge is rarely practical or possible. Formulas for the computation of size of charge vary with the types of steel—structural, high carbon, and so forth. Placement, frequently harder to accomplish on steel structures, is aided by the use of plastic explosive.

75. Type of Explosive

Steel cutting charges are selected because of their cutting effect and adaptability to placement. Plastic explosive (C4) is one of the most desirable as it has the highest detonation velocity and therefore the most cutting power. It is easily molded or cut to fit tightly into the grooves and angles of the target, particularly structural steel, chains, and steel cables. TNT, on the other hand is adequate, generally available, and cast into blocks that may be readily assembled and fixed to the target.

76. Size of Charge Determined by Type and Size of Steel

a. Types of Steel.

(1) *Structural.* Examples of this are I-beams, wide-flanged beams, channels, angle sections, structural tees, and steel plates used in building or bridge construction. These are the types of steel usually present in demolition projects. The formula in *b*(1) below is applicable to structural steel, except for cutting slender structural bars (2 inches or less in diameter), where placement difficulties require the use of the formula in *b*(2) below.

(2) *High-carbon.* This type of steel is used in the construction of metal-working dies and rolls. The formula in *b*(2) below, is applicable.

(3) *Alloy.* Gears, shafts, tools, and plowshares generally are made of alloy steel. Chains and cables also are often made from alloy steel; some, however, are made of high-carbon steel. The formula in *b*(2) below, applies to alloy steel.

b. Calculation of Charges.

(1) *Formula for structural steel.* Charges to cut I-beams, built-up girders, steel plates, columns, and other structural steel sections are computed by formula as follows:

$P = \frac{3}{8} A$

P = pounds of TNT required,

A = cross-sectional area, in square inches, of the steel member to be cut, and

$\frac{3}{8}$ = constant.

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(2) *Formula for other steels.* The formula below is recommended for the computation of cutting charges for high-carbon or alloy steel, such as found in machinery. It is also satisfactory for steel bars, such as concrete reinforcing rods, where the small size makes charge placement difficult or impossible, and for chains, cables, strong forging, steel rods, machine parts, and high-strength tools of a diameter of 2 inches or less.

$P = D^2$
P = pounds of TNT
D = diameter in inches of section to be cut.

Note. On bars, if either dimension exceeds 2 inches, use $P = \frac{3}{8} A$.

(3) *Railroad rails.* The size of railroad rail is usually indicated in terms of weight per yard—an 80-pound rail weighs 80 pounds per yard. The amount of explosive needed to cut an 80-pound or lighter rail is a ½-pound charge of TNT placed against the web. The charge needed to cut a larger rail is 1 pound of TNT placed against the web. Generally, rails that measure more than 5 inches overall in height weigh more than 80 pounds per yard.

(4) *"Rounding-off" rule.* Charges calculated by formulas should be "rounded-off" to the next higher unit package of explosive. For example, if calculations show that 3 27/64 pounds of explosive is needed, 3½-pounds is the correct weight to use. If a ½-pound charge is required, and only 2½-pound blocks are available, cut the blocks to proper size. For charges other than TNT, apply the "rounding off" rule at completion of correction factor calculations.

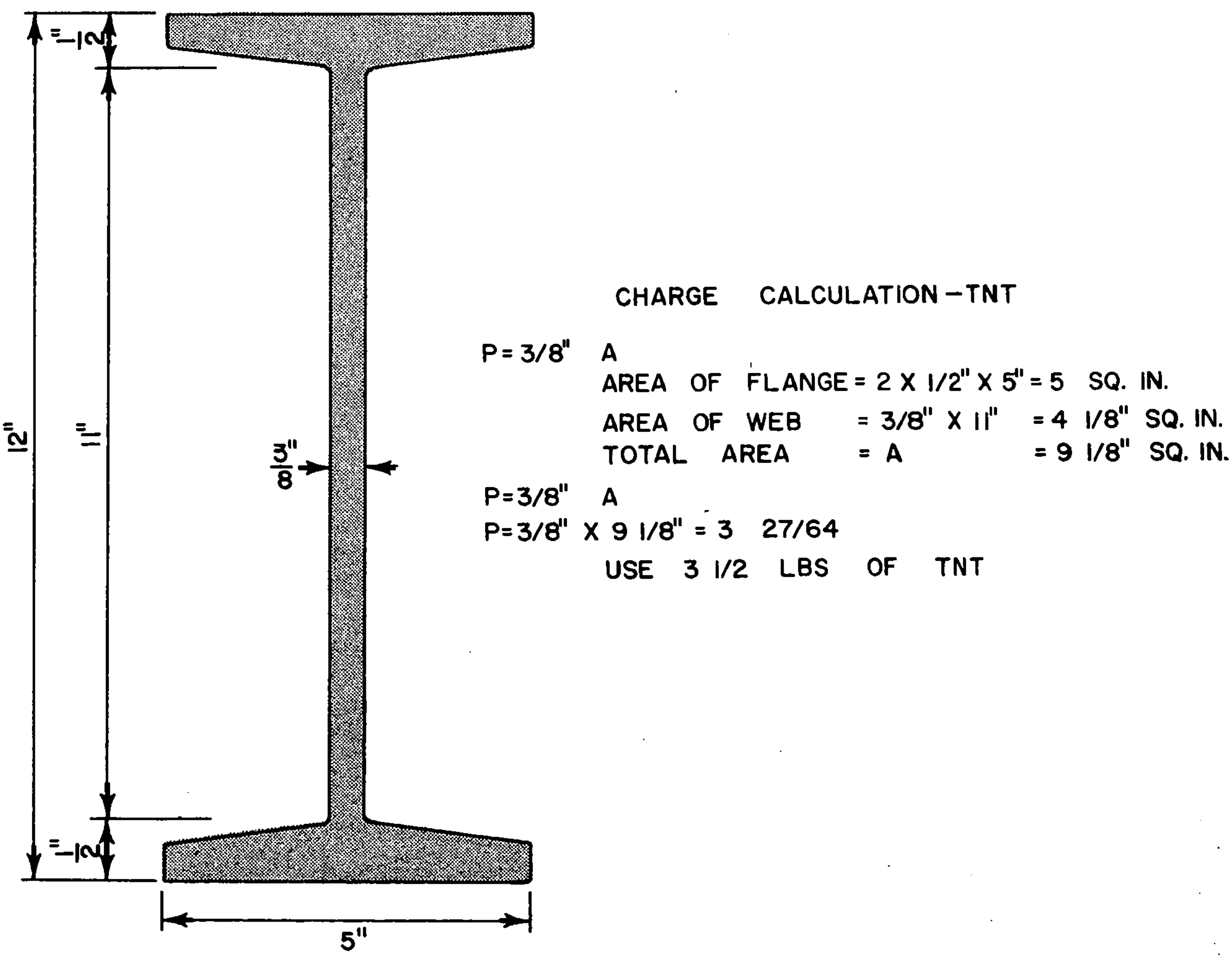


Figure 61. Calculation of charge for cutting steel I-beam.

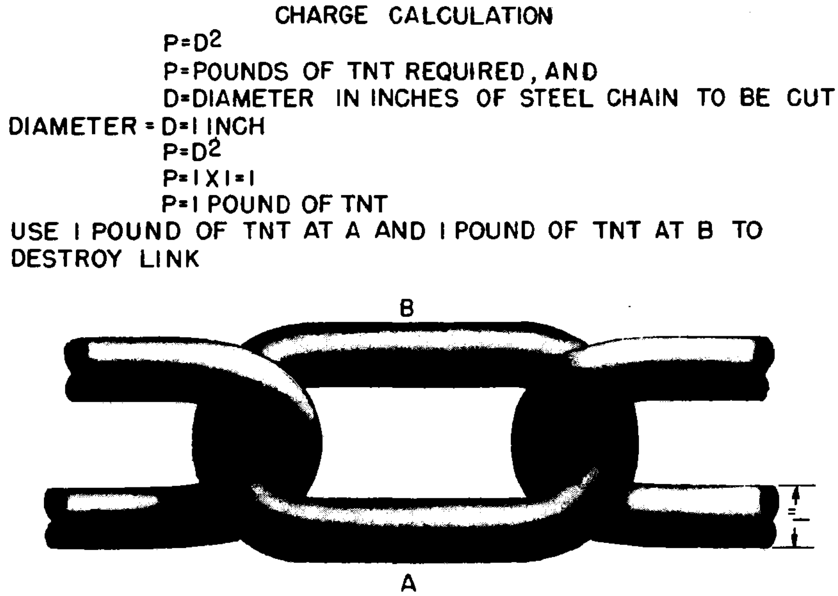


Figure 62. Calculation of charge to cut steel chain.

(5) *Problem: cutting steel* **I**-*beam*. Determine the amount of TNT required to cut the steel **I**-beam shown in figure 61. The solution is given in the figure.

(6) *Problem: explosives other than TNT*. Determine the amount of C4 explosive required to cut the steel **I**-beam in figure 61.

The amount of TNT $=3\frac{27}{64}$.
As C4 is 1.34 times as effective as TNT (col. 4, table IV, and par. 66*a*).

$P \text{ (of C4)} = \frac{219/64}{1.34} = 2.5$ pounds.

(7) *Problem: cutting steel chain*. How much TNT is needed to cut the steel chain in figure 62? The solution is given in figure 62. Notice that the link is cut in two places (one cut on each side) to cause complete failure. If the explosive is long enough to bridge both sides of the link, use only one charge; but if it is not, use two separately-primed charges.

(8) *Use of the table in making calculations*. Table V shows the correct weight of TNT necessary to cut steel sections of various dimensions calculated from the formula $P=\frac{3}{8}A$. In using this table:

- (*a*) Measure separately the rectangular sections of members.
- (*b*) Find the corresponding charge for each section by using the table.
- (*c*) Total the charges for the sections.
- (*d*) Use the next larger given dimension if dimensions of sections do not appear in the table.

Caution: **Never use less than the calculated amount.**

(9) *Problem*. The problem in figure 61 may be solved as follows:

Charge for flanges:	Charge for web:
width = 5 inches	width = 11 inches
thickness = ½ inch	thickness = ⅜ inch
Charge from table = 1.0 pounds	Charge from table = 1.7 pounds

Total charge 2 flanges $=2\times 1.0=2.0$ pounds
web $=1\times 1.7=1.7$ pounds
3.7 pounds

Use 4 pounds of TNT.

Note. As table V gives no weight of explosive for an 11-inch web, the next larger dimension, 12 inches, is used as indicated in (8)(*d*) above.

77. Placement of Charge

a. Steel Sections. The size and type of a steel section determine the placement of the explosive charge. Some elongated sections may be cut by placing the explosive on one side of the section completely along the line of rupture. More explosive should be placed against the thicker portion of the cross section than against the thinner portions. In some steel trusses in which the individual members are fabricated from two or more primary sections, such as angle irons or bars separated by spacer washers or gusset plates, the charge has to be distributed on opposite sides of the member to be cut, with the opposing portions of the charge slightly offset to produce a shearing action (fig. 63).

Table V. Steel Cutting Charges

Average thickness of sections in inches	Pounds of explosive* for rectangular steel sections of given dimensions — Width of section in inches												
	2	3	4	5	6	8	10	12	14	16	18	20	24
¼	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.3	1.5	1.7	1.9	2.3
⅜	0.3	0.5	0.6	0.7	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.4
½	0.4	0.6	0.8	1.0	1.2	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.5
⅝	0.5	0.7	1.0	1.2	1.4	1.9	2.4	2.9	3.3	3.8	4.3	4.7	5.7
¾	0.6	0.9	1.2	1.4	1.7	2.3	2.8	3.4	4.0	4.5	5.1	5.7	6.8
⅞	0.7	1.0	1.4	1.7	2.0	2.7	3.3	4.0	4.6	5.3	6.0	6.6	7.9
1	0.8	1.2	1.5	1.9	2.3	3.0	3.8	4.5	5.3	6.0	6.8	7.5	9.0

*TNT.

To use table:
1. Measure rectangular sections of members separately.
2. Using table, find charge for each section.
3. Add charges for sections to find total charge.
4. *Never* use less than calculated charge.
5. If dimensions of sections do not appear on table, use the next larger dimension.

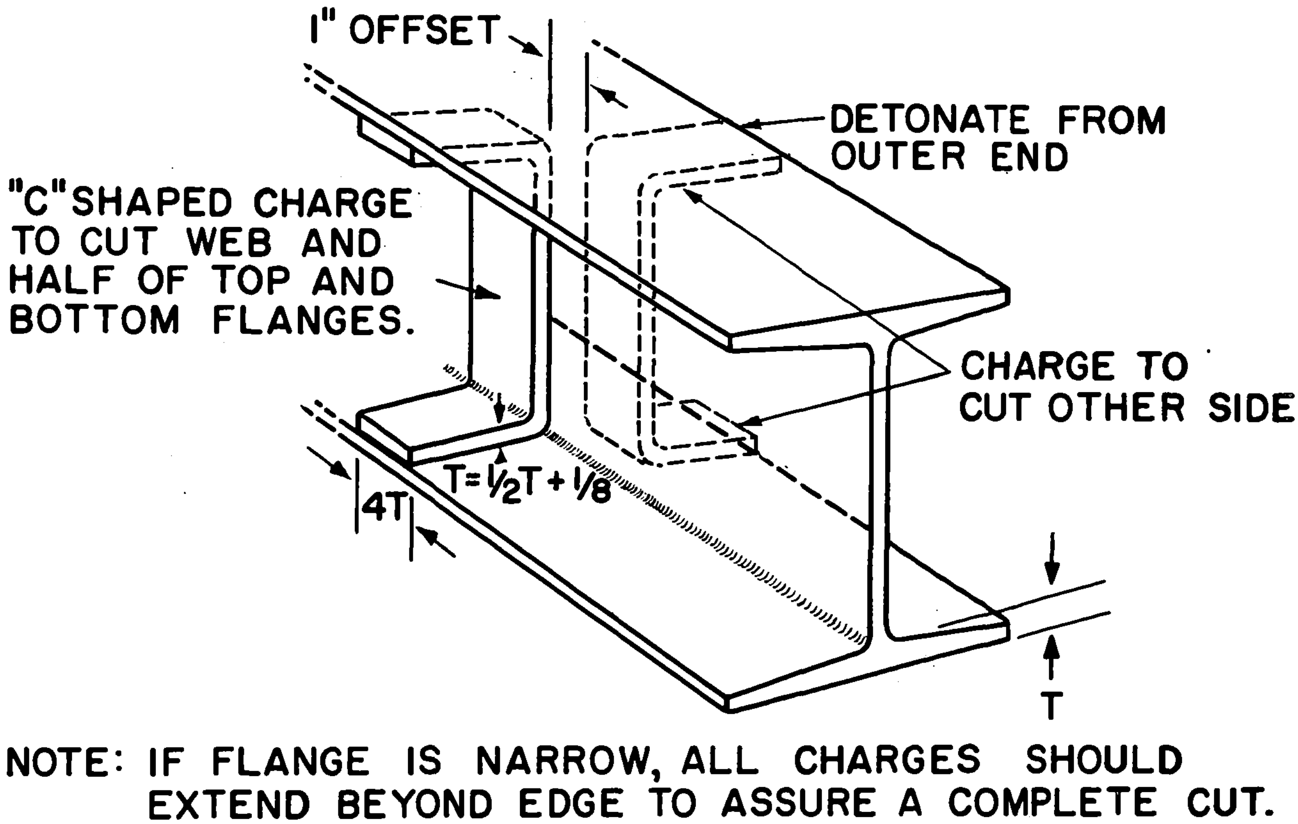


Figure 63. Explosive staggered to give shearing effect.

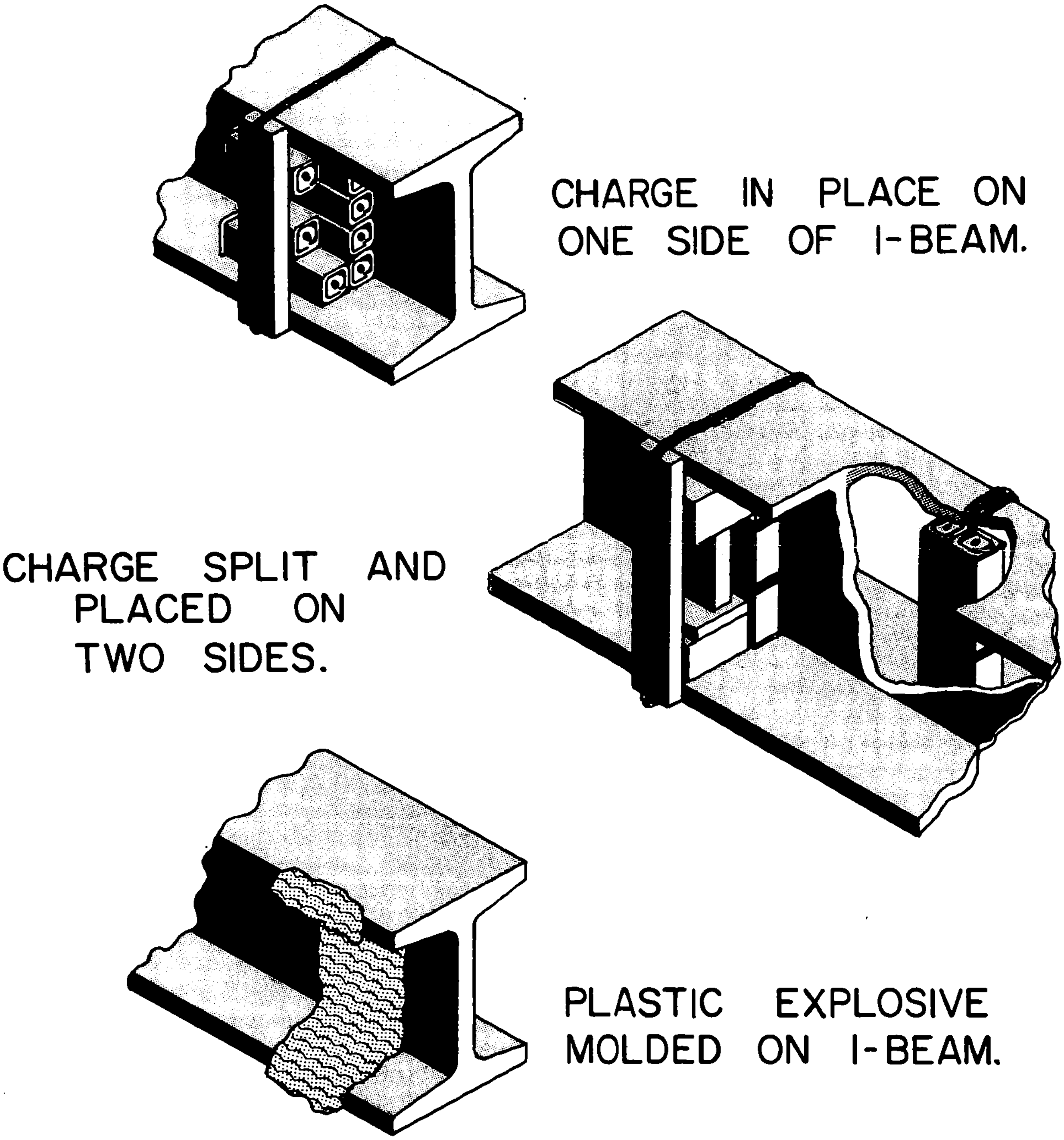


Figure 64. Placement of charges on steel members and railroad rails.

Heavier H-beams, wide flange beams, and columns may also require auxiliary charges placed on the outside of the flanges. Care must be taken to insure that opposing charges are never directly opposite each other, otherwise they tend to neutralize the explosive effect.

b. Rods, Chains, and Cables. Block explosive is not recommended for cutting steel rods, chains, and cables if plastic explosive is available. Composition C4 should be placed only on one side of the member to be cut (fig. 64). The width of the charge should be slightly less than ½ of the circumference; and the length, at least three times the thickness of the member. Usually the charge should be less than 1 inch thick. It should be detonated from one end in order to produce a major cross fracture at the opposite end.

c. Built-Up Members. Built-up members frequently have an irregular shape, which makes it difficult to obtain a close contact between the explosive charge and all of the surface. If it is impractical to distribute the charge properly to obtain close contact, the amount of explosive should be increased.

d. Irregular Steel Shapes. Composition C4 is the best explosive for cutting irregular steel shapes because it is easily molded or pressed into place to give maximum contact. A light coating of adhesive compound applied to the steel surface will help to hold the explosive on the target. If TNT is used, the blocks should be removed from their containers. Also, mud or grease should be used to fill in any air gaps between separate blocks and between the blocks and the steel, if necessary.

e. Securing Explosives in Place. All explosives must be tied, taped, or wedged in place unless they rest on horizontal surfaces and are not in danger of being jarred out of place.

f. Precautions. In cutting steel the charge should be placed on the same side as the firing party, as explosive charges throw steel fragments (missiles) long distances as high velocities. Guards should be posted prior to firing to prevent all persons from approaching the danger area. The firing detachment and all other soldiers nearby *must* take cover during firing. *The explosive charge must not be fired until everyone is out of danger.*

78. Confinement of Charge Usually Impractical

The formulas, above, determine the amount of explosive used for untamped or unconfined charges. Because of the nature of certain structures, like bridges, that have chains, cables, and other steel members of various sizes and shapes, tamping is generally impossible or impractical.

Section IV. PRESSURE CHARGES

79. Critical Factors

Factors to be considered in the use of pressure charges are those of other charges—selection, size placement, and confinement of the explosive. These charges are used primarily against simple span reinforced concrete T-beam bridges. Placement is important. The purpose is to partially breach and thus overload the span, which causes a break at midspan and permits the bridge to pull free from the abutments or piers. Total demolition is seldom necessary. The formula for this type of bridge (par. 81) is not adequate for computing charges against the continuous span reinforced concrete T-beam bridge. Pressure charges may be tamped or untamped, depending upon characteristics of the target and tactical conditions.

80. Type of Explosive

TNT and the M1 chain and M2 demolition blocks (tetrytol) are generally used in pressure charges. Because pressure charges usually range from 60 to 80 pounds, tetrytol blocks are advantageous because they come in haversacks containing 8 blocks or 20 pounds of explosive each.

81. Size of Charge

a. Formula for Tamped Pressure Charges. The amount of TNT required for a tamped pressure charge is calculated by the formula below. If explosive other than TNT is used, the calculated value must be adjusted.

$P = 3H^2T$

P = pounds of TNT required for each stringer
H = height of stringer (including thickness of roadway) in feet, and
T = thickness of stringer in feet.

However, the values of H and T, if not whole numbers should have the fraction expressed in ¼-foot increments by rounding off to the next higher ¼-foot dimension. H and T are never considered less than 1 foot.

b. Formula for Untamped Pressure Charges. The value calculated for P by the above formula is increased by one-third if the pressure charge is not tamped to a minimum of 10 inches.

c. Problem: Pressure Charges. Determine the amount of TNT required to destroy the bridge span shown in figure 65. The solution to this problem is found in the figure. Notice that the quantity of explosive given by the formula refers to the charge for each stringer. Thus, five of these 34-pound charges should be placed as shown in the figure.

d. Use of Table in Making Calculations. Table VI gives the various weights of TNT required to provide suitable tamped pressure charges. The weights of TNT in the table were calculated from the formula $P=3H^2T$ and the values were rounded off to the next highest pound. To use the table proceed as follows:

(1) Select the appropriate value in the "Height of beam" column.

(2) Read the weight of the TNT from the column corresponding to the thickness of the beam.

e. Example. The height of the beam in the problem in figure 65 is 36 inches and the thickness is 15 inches. In table VI (36-in. ht. and 15-in. col.), the weight of TNT for the tamped pressure charge is indicated as 34 pounds. For untamped charges the weight values given in the table are increased by one-third.

82. Placement of Charge

The correct amount of explosive is placed on the roadway over the centerline of each stringer (fig. 65), and alined midway between the ends of the span. If a curb or side rail prevents placing the charge directly above the outside stringer, it is placed against the curb or side rail. This does not require an increase in the explosive charge.

83. Confinement of Charge

Pressure charges should be tamped whenever possible. Effective tamping requires a minimum of 10 inches of material. If, for any reason, tamping should be impossible, the charge is increased as provided by formula or table. All charges are primed to fire simultaneously.

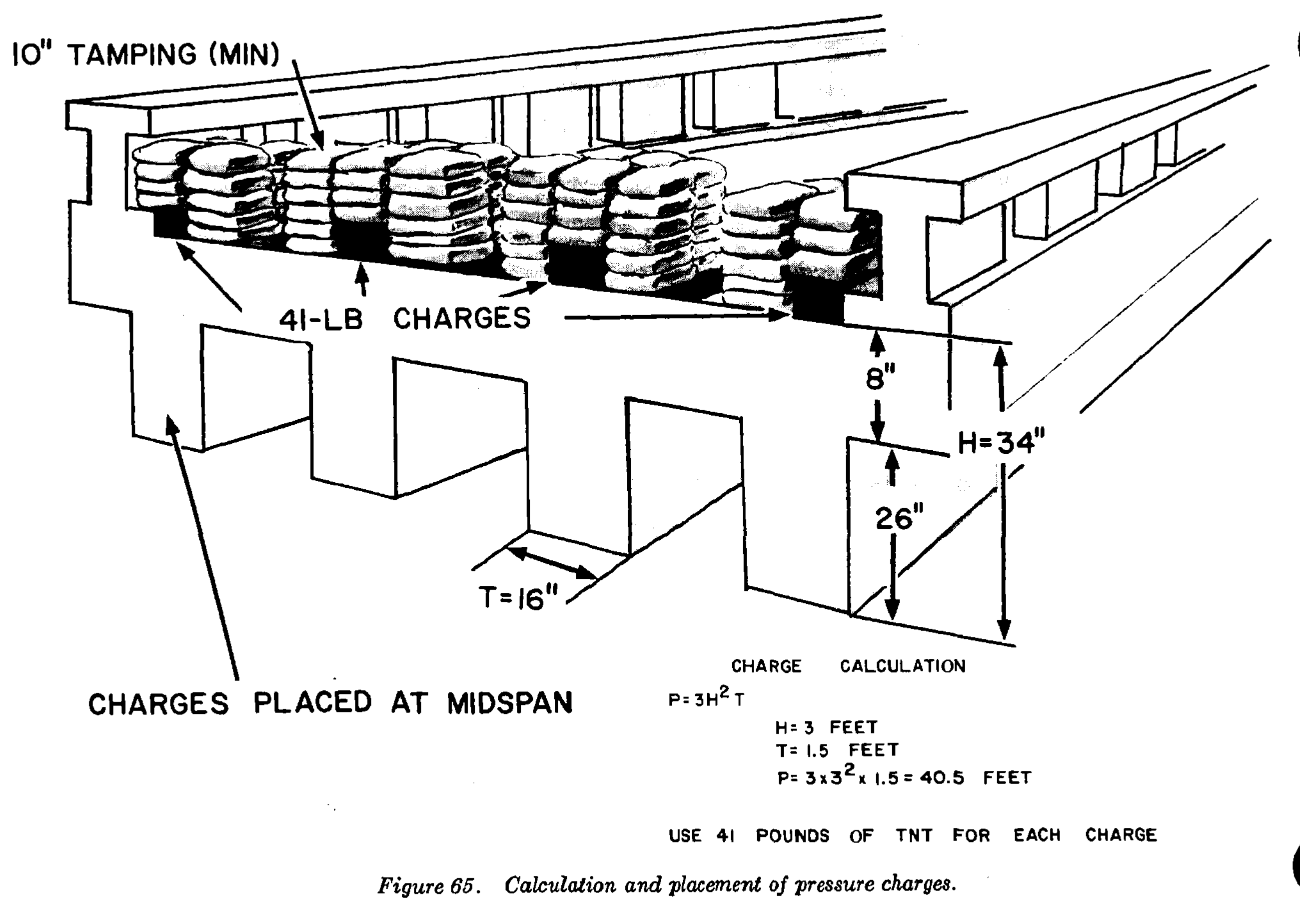


Figure 65. Calculation and placement of pressure charges.

Table VI. Pressure Charges

Pounds of explosive for each beam (tamped charges)* (TNT)

Height of beam in feet	Thickness of beam in feet								
	1 (12 in.)	1¼ (15 in.)	1½ (18 in.)	1¾ (21 in.)	2 (24 in.)	2¼ (27 in.)	2½ (30 in.)	2¾ (33 in.)	3 (36 in.)
1 (12 in.)	3								
1¼ (15 in.)	5	6							
1½ (18 in.)	7	9	11						
1¾ (21 in.)	10	12	14	16					
2 (24 in.)	12	15	18	21	24				
2¼ (27 in.)	16	19	23	27	31	35			
2½ (30 in.)	19	24	29	33	38	43	47		
2¾ (33 in.)	23	29	34	40	46	51	57	63	
3 (36 in.)	27	34	41	48	54	61	68	75	81
3¼ (39 in.)	32	40	48	56	64	72	80	88	95
3½ (42 in.)	37	46	56	65	73	83	92	101	111
3¾ (45 in.)	43	53	64	74	85	95	106	116	127
4 (48 in.)	48	60	72	84	96	108	120	132	144
4¼ (51 in.)	55	68	82	95	109	122	136	149	163
4½ (54 in.)	61	76	92	107	122	137	152	167	183
4¾ (57 in.)	68	85	102	119	136	153	170	187	203
5 (60 in.)	75	94	113	132	150	169	188	207	225

*Increase weights by ⅓ for untamped charges. (Minimum tamping required is 10 inches.)

Section V. BREACHING CHARGES

84. Critical Factors

The size, placement, and confinement of the breaching charge are critical factors, with the size and confinement of the explosive being relatively more important. This is because of the strength, hardness, and sheer bulk of the materials to be breached in most operations. Breaching charges are applied chiefly to the destruction of bridge piers, bridge abutments, and permanent field fortifications. High explosive breaching charges, detonated in or against concrete, masonry, and rock must produce a shock so intense that it breaks or shatters the material. The metal reinforcing bars often found in concrete are not always cut by breaching charges.

85. Type of Explosive

TNT and the tetrytol blocks (M1 chain and M2) are the most effective breaching explosives. Breaching charges being relatively large, the tetrytol blocks, usually in 20-pound kits, are more readily adaptable, and, being more powerful than TNT, are economical in explosive.

86. Size of Charge

a. Calculation Formula. The size of a charge required to breach concrete, masonry, rock, or similar material is calculated by the formula below. By proper adjustment of the *P*-value, the charge size for any other explosive may be readily determined.

$P = R^3KC$

P = pounds of TNT required

R = breaching radius, in feet (*b* below)

K = a material factor, given in table VII, which reflects the strength and hardness of the material to be demolished (*c* below)

C = a tamping factor, given in figure 66, which depends on the location and tamping of the charge (*d* below)

Note. For breaching walls 1 foot thick or less, increase the total calculated charge by 50 percent. Add 10 percent for charges under 50 pounds.

b. Breaching Radius R. The breaching radius *R* is the distance in feet from an explosive, in which all material is displaced or destroyed. The breaching radius for external charges is the thickness of the mass to be breached. The breaching radius for internal charges is one-half the thickness of the mass to be breached, if the charge is placed midway into the mass. If holes are drilled less than halfway into the mass, the breaching radius becomes the longer distance from the center of the charge to the outside of the mass. For example, if a 4-foot wall is to be

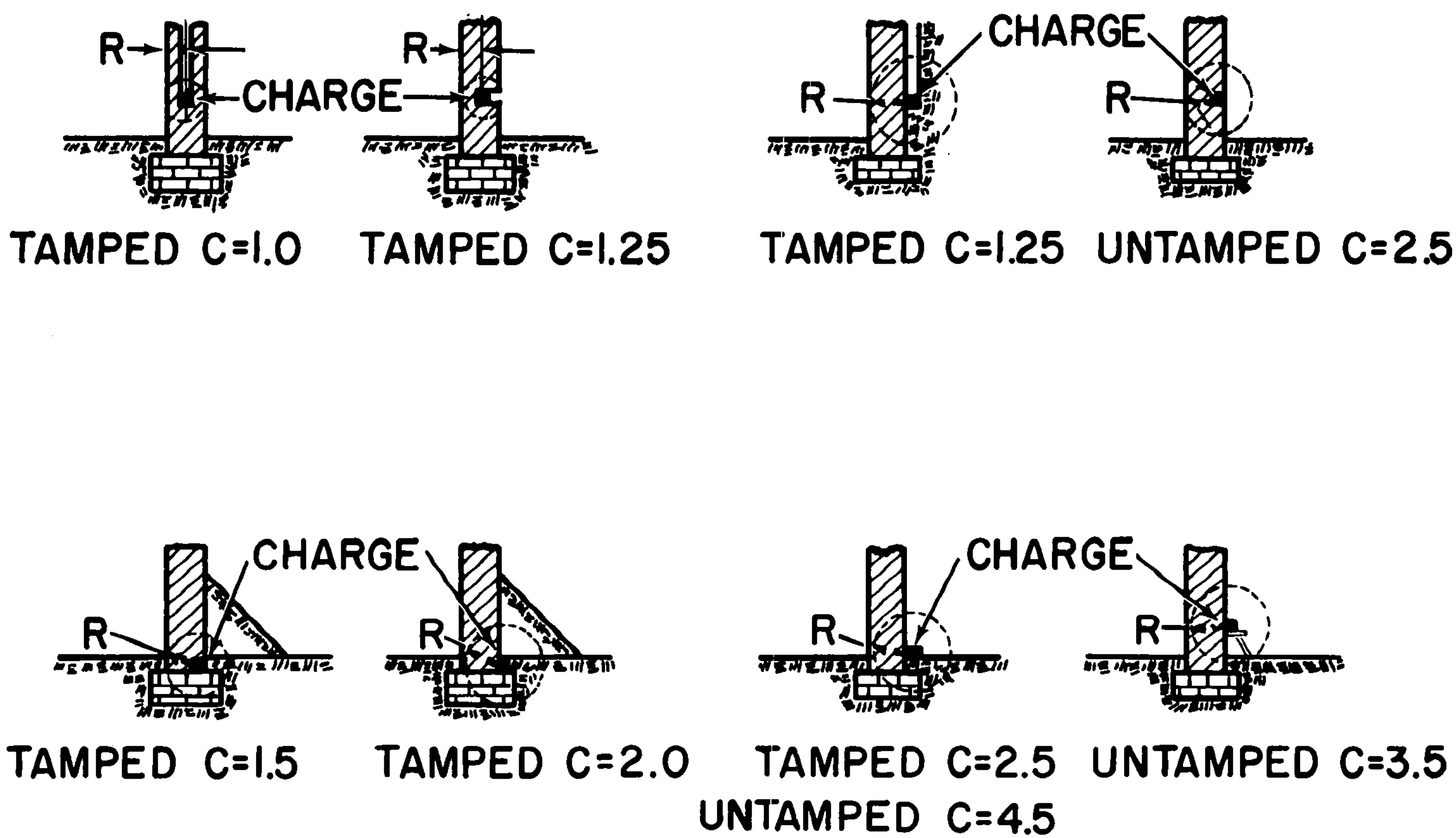


Figure 66. Value of C (tamping factor) for breaching charges.

Table VII. Values of Material Factor K for Calculating Breaching Charges

Material	Breaching radius	K
Ordinary earth	All values	0.05
Poor masonry, shale and hardpan; good timber and earth construction	All values	0.23
Good masonry, ordinary concrete, rock	Less than 3 feet	0.35
	3 feet to less than 5 feet	.28
	5 feet to less than 7 feet	.25
	7 feet or more	.23
Dense concrete, first-class masonry	Less than 3 feet	0.45
	3 feet to less than 5 feet	.38
	5 feet to less than 7 feet	.33
	7 feet or more	.28
Reinforced concrete (concrete only; will not cut steel reinforcing)	Less than 3 feet	0.70
	3 feet to less than 5 feet	.55
	5 feet to less than 7 feet	.50
	7 feet or more	.43

breached by an internal charge placed 1 foot into the mass, the breaching radius is 3 feet. If it is to be breached by a centered internal charge, the breaching radius is 2 feet. The breaching radius is 4 feet if an external charge is used.

c. Material Factor K. K is the factor that reflects the strength and hardness of the material to be breached. Table VII gives values for the factor K for various types of material. When it is not known whether or not concrete is reinforced, it is assumed to be reinforced.

d. Tamping Factor C. The value of tamping factor C depends on the location and the tamping of the charge. Figure 66 shows typical methods for placing charges and gives values of C to be used in the breaching formula with both tamped and untamped charges. In selecting a value of C from figure 66, a charge tamped with a solid material such as sand or earth is not considered fully tamped unless it is covered to a depth equal to the breaching radius.

87. Placement of Charge

a. Positions. In the demolition of piers and walls, the positions for the placement of explosive charges are rather limited. Unless a demolition chamber is available, the charge (or charges) may be placed against one face of the target either at ground level, somewhat above ground level, or beneath the surface. A charge placed above ground level is more effective that one placed directly on the ground. When several charges are required to destroy a pier, slab, or wall and elevated charges are desired, they are distributed equally at no less than 1 breaching radius high from the base of the object to be demolished. In this manner the best use is obtained from the shock waves of the blast. All charges are thoroughly tamped with damp soil or filled sandbags if time permits. For piers, slabs, or walls partially submerged in water, charges are placed below the waterline. If underwater demolition is essential, use the tamping factor for the placement of tamped charges above ground.

b. Number of Charges. The number of external charges required for demolishing a pier, slab, or wall is determined by the formula—

$$N = \frac{W}{2R}$$

N = number of charges
W = width of pier, slab, or wall, in feet,
R = breaching radius in feet (par. 86*b*)

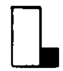
If the calculated value of N has a fraction less than ½, the fraction is disregarded, but if the calculated value of N has a fraction of ½ or more, the value is "rounded off" to the next highest whole number. An exception to this general rule is in calculated N-value between 1 and 2, in which a fraction less than ¼ is disregarded, but a fraction of ¼ or more is rounded off to the next higher whole number, or 2.

c. Use of Table in Making Calculations. Table VIII gives the weight of TNT required to breach reinforced and dense concrete targets. The weights of TNT in the table were calculated from the formula $P = R^3KC$ and the values were rounded off to the next highest pound.

d. Example. Using table VIII, calculate the amount of TNT required to breach a reinforced concrete wall 7 feet in thickness with an untamped charge placed at a distance R above the ground.

Table VIII. Breaching charges

Table XI. Breaching Charges

THICKNESS OF CONCRETE IN FEET	REINFORCED CONCRETE				(DENSE) UNREINFORCED CONCRETE			
		(TAMPED) 		(TAMPED) 		(TAMPED) 		(TAMPED) 
1	5	5	5	5	3	3	3	3
2	22	8	28	16	14	5	18	10
3	52	21	67	41	40	15	51	29
4	124	49	159	88	86	34	110	61
5	219	79	282	157	145	52	186	104
6	378	135	486	270	250	89	321	179
7	517	185	663	369	337	120	433	241
8	771	276	991	551	502	170	646	359
9	1098	392	1411	784	715	255	919	511
10	1505	540	1935	1075	980	350	1260	700

NOTE: At least 5 lbs. for reinforced concrete.
At least 3 lbs. for dense concrete.

From the table (7-foot thickness and untamped charges placed at a distance R above the ground columns) the required weight of TNT is 517 pounds.

88. Confinement of Charge

External breaching charges, if placed at the base of the pier or abutment on dry land are easily tamped with earth or sandbags; the water in underwater charges serves as tamping. External charges placed higher, about ⅓ of the way up from the base and above ground or water, are difficult if not impossible to tamp. Charges may be placed in boreholes where they can readily be tamped.

Section VI. CRATERING AND DITCHING CHARGES

89. Critical Factors

Cratering and ditching charges, like other demolition charges, to be effective depend on correct selection, size, placement, and confinement of the explosive. Placement and spacing are critical, and charges are placed according to formula. Confinement by stemming or tamping is necessary for proper effect.

a. Explosive. Cratering and ditching require an explosive with a different effect from that required for cutting and breaching—a heaving effect produced by explosives less powerful than TNT, tetrytol, and Composition C4. A special cratering charge, ammonium nitrate, issued in a waterproof metal container, is used. When the ammonium nitrate charge is not available, other explosives may be substituted.

b. Size and Placement of Charge.

(1) *Basic factors.* In deliberate cratering holes are bored to specific depths and spaced according to computation by formula. In hasty cratering, holes are more shallow, contain less explosive and are not necessarily spaced by formula. Deliberate craters when formed are generally a minimum of 8 feet deep and hasty craters, a minimum of 7 feet deep. In ditching, test shots are made and the diameter and depth are increased as required.

(2) *Breaching hard-surfaced pavements for cratering charges.* Hard-surfaced pavement of roads and airfields is breached so that holes may be dug for cratering charges. This is done effectively by exploding tamped charges on the pavement surface. A 1-pound charge of explosive is used for each 2 inches of pavement thickness. It is tamped with material twice as thick as the pavement. The pavement may also be breached by charges placed in boreholes drilled or blasted through it. A shaped charge readily blasts a small diameter borehole through the pavement and into the subgrade. Concrete should not be breached at an expansion joint, because the concrete will shatter irregularly. Detonating cord may be used to widen small charge holes. An M2A3 shaped charge (fig. 7) detonated 30 inches above any kind of soil will produce a borehole deep enough to accept a cratering charge (table IX). But since these shaped-charge boreholes are usually tapered in diameter, they may require some enlarging by means of a post-hole auger or other device to permit the placement of the cratering charge.

c. Confinement of Charge. Charges at cratering sites and antitank ditching sites are placed in boreholes and properly stemmed. Those at culvert sites are tamped with sandbags.

90. Effective Road Craters

Road craters, to be effective obstacles, must be too wide for spanning by track-laying vehicles and too deep and steep-sided for any vehicle to pass through them. They must also be large enough to tie into natural or manmade obstacles at each end. Antitank and antipersonnel mines are often placed at the site to hamper repair operations and thus increase the effectiveness of the crater.

91. Deliberate Road Crater

A deliberate road crater may be made in all materials except loose sand, regardless of the type of road surface. The method shown in figure 70 produces a clean V-shaped crater a minimum of 8 feet deep and 25 feet wide extending about 8 feet beyond each end charge. The method of placing charges is as follows:

a. Bore the holes 5 feet apart, center-to-center, in line across the roadway. The end holes are 7 feet deep and the others are alternately 5 feet and 7 feet

Table IX. Size of Boreholes Made by Shaped Charges in Various Materials

				M3 shaped charge	M2A3 shaped charge
1	Reinforced concrete	Maximum wall thickness that can be perforated		60 in.	36 in.
2		Depth of penetration in thick walls		60 in.	30 in.
3		Diameter of hole (in.).	Entrance	5 in.	3½ in.
4			Average	3½ in.	2¾ in.
5			Minimum	2 in.	2 in.
6		Depth of hole with second charge placed over first hole		84 in.	45 in.
7	Armor plate	Perforation		At least 20 in.	12 in.
8		Average diameter of hole		2½ in.	1½ in.
9	Permafrost	Depth of hole with 50-in. standoff		72 in.	N/A
10		Depth with 30-in. standoff		N/A	72 in.
11		Depth with 42-in. standoff		N/A	60 in.
12		Diameter of hole with average (30-in.) standoff		N/A	6 in. to 1½ in.
13		Diameter of hole with 50-in. standoff		8 in. to 5 in.	N/A
14		Diameter of hole with normal standoff		*26–30 in. to 7 in.	26–30 in. to 4 in.
15	Ice	Depth with average (42-in.) standoff		12 ft.	7 ft.
16		Diameter with average (42-in.) standoff		6 in.	3½ in.

*Boreholes made by shaped charges are cone-shaped. The diameters shown in this table are top and bottom measurements.

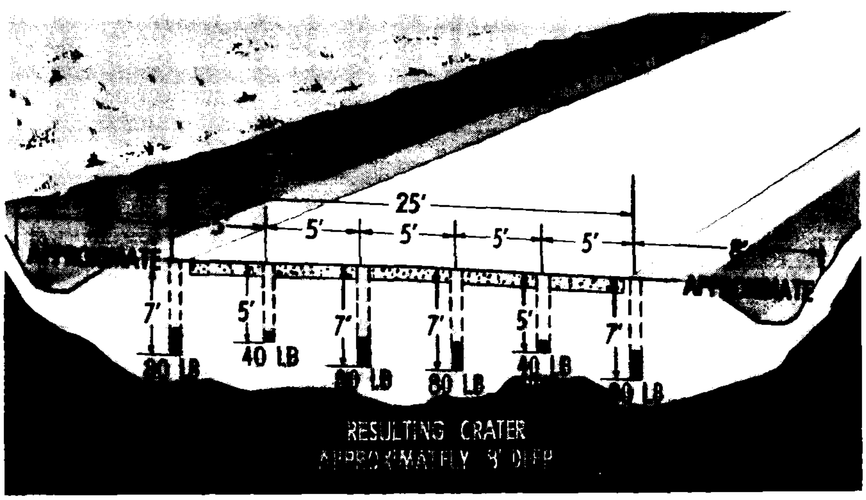


Figure 67. Placement of charges for deliberate road crater.

deep. The formula for the computation of the number of holes is—

$$N=\frac{L-16}{5}+1$$

L = length of crater

Any fractional number of holes is rounded off to the next highest number (fig. 67).

b. Place 80 pounds of explosive in the 7-foot holes and 40 pounds of explosive in the 5-foot holes. Two 5-foot holes must not be next to each other. If they are so calculated, one of them must be made a 7-foot hole. The resulting two adjacent 7-foot holes may be placed anywhere along the line.

c. Prime all charges and connect them to fire simultaneously. A dual firing system should be used.

d. Place a 1-pound primer in each hole on top of the can for dual priming, if the standard cratering charge is used.

e. Stem all boreholes with suitable material.

92. Hasty Road Crater

Although a hasty road crater takes less time and less explosive for construction than a deliberate road crater, it may be less desirable because of its depth and shape. The hasty method is especially adaptable for cratering in hard soil (fig. 68). The method described below forms a crater about 1½ times deeper and 5 times wider than the depth of the boreholes, and extends about 8 feet beyond each end charge. The sides have a slope of 30° to 60° depending on the soil. Craters formed by boreholes less than 4 feet deep and loaded with charges less than 40 pounds are ineffective against tanks. The following hasty cratering method has proved satisfactory:

a. Dig all boreholes to the same depth. This may vary from 2½ to 5 feet, depending upon the size of the crater needed. Space the holes 5 feet apart, center-to-center across the road.

b. Load the boreholes with 10 pounds of explosive per foot of depth.

c. Prime the charges as for deliberate cratering.

d. Stem all holes with suitable material.

93. Cratering at Culverts

A charge detonated to destroy a culvert not more than 15 feet deep may at the same time produce an effective road crater. Culverts deeper than 15 feet, however, should be destroyed by other methods, as they require an excessive amount of labor and explosive, and produce a crater larger than necessary.

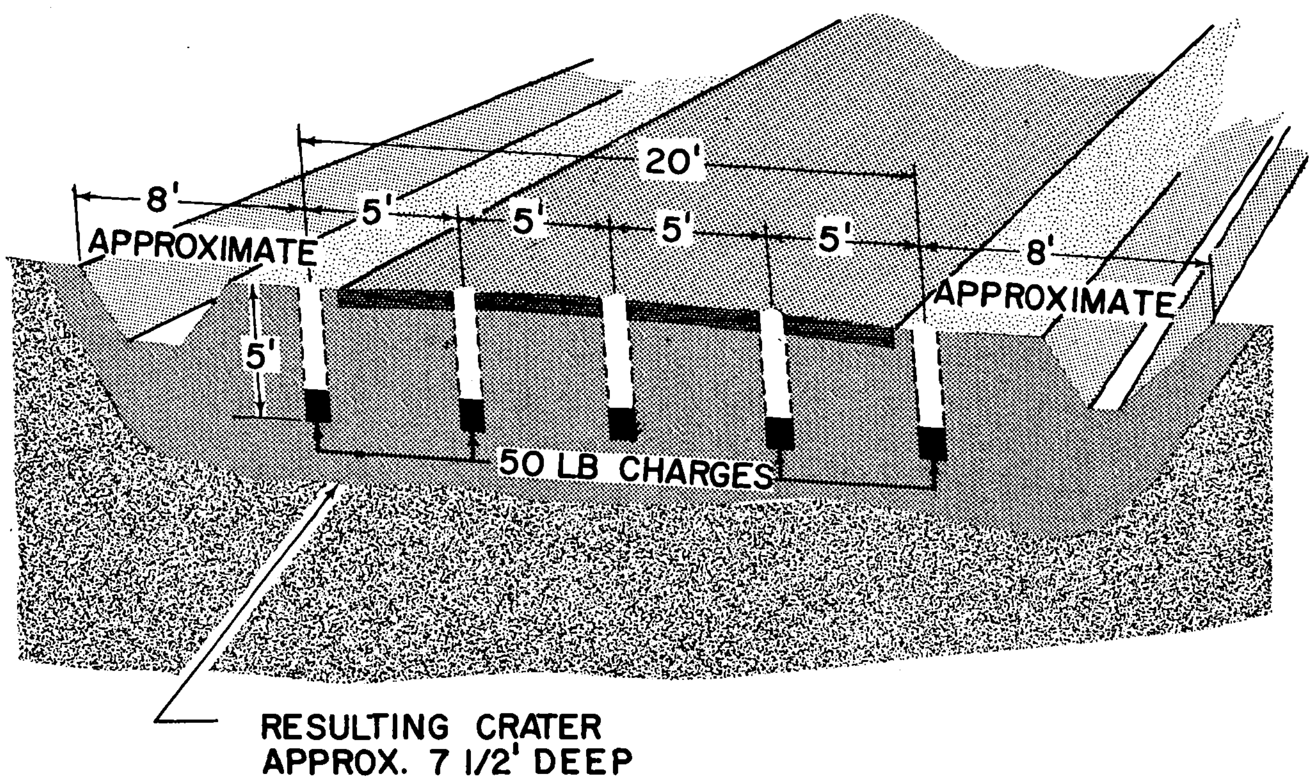


Figure 68. Placement of charges for hasty road crater.

Explosive charges should be primed for simultaneous firing, and thoroughly tamped with sandbags. Culverts with 5 feet or less of fill may be destroyed by explosive charges placed in the same manner as in hasty road cratering (par. 92). Concentrated charges equal to 10 pounds per foot of depth are placed in boreholes at 5-foot intervals in the fill above and alongside the culvert.

94. Antitank Ditch Cratering

a. Construction. In open country, antitank ditches are constructed to strengthen prepared defensive positions. As they are costly in time and effort, much is gained if the excavation can be made by means of cratering charges. To be effective, an antitank ditch must be wide enough and deep enough to stop an enemy tank. It may be improved by placing a log hurdle on the enemy side and the spoil on the friendly side. Medium tanks are usually stopped by a ditch 6 feet deep and 12 feet wide. For heavy tanks, the ditch must be at least 8 feet deep and 25 feet wide at the top. Ditches are improved by digging the face on the friendly side nearly vertical by means of handtools.

b. Deliberate Cratering Method. The deliberate cratering method outlined in paragraph 91 is adequate for the construction of heavy tank ditches in most types of soil.

c. Hasty Cratering Method. Ditches for medium tanks may be constructed by placing 40 pounds of cratering explosive in 4-foot holes spaced 5 feet apart. This makes a ditch approximately 6 feet deep and 20 feet wide. A heavy antitank ditch may be constructed by placing 50 pounds of cratering explosive in 5-foot holes, and spacing the holes at 5-foot intervals. The ditch will be approximately 8 feet deep and 25 feet wide.

95. Blasting of Ditches

In combat areas ditches may be constructed to drain terrain flooded by the enemy or as initial excavations for the preparation of entrenchments. Rough open ditches 2½ to 12 feet deep and 4 to 40 feet wide may be blasted in most types of soils. Detailed instructions for blasting are found in TM 5–335. A brief outline of the method is given below.

a. Test Shots. Before attempting the actual ditching, make test shots to determine the proper depth, spacing, and weight of charges needed to obtain the required results. For small ditches, make beginning test shots with holes 2 feet deep and 18 inches apart and then increase the size of the charge and the depth as required. A rule of thumb for ditching is to use 1 pound of explosive per cubic yard of earth in average soil.

b. Alinement and Grade. Mark the ditch centerline by transit line or expedient means and drill holes along it. When a transit or hand level is used, the grade of the ditch may be accurately controlled by checking the hole depth every 5 to 10 holes and at each change in grade. In soft ground, the holes may be drilled with a miner's drill or earth auger. Holes are loaded and tamped immediately to prevent cave-ins and insure that the charges are at proper depth. Ditches are sloped at a rate of 2 to 4 inches per 100 feet.

c. Methods of Loading and Firing.

(1) *Propagation method.* Here the hole or holes at one end of the ditch are primed so that the concussion from each charge detonates the succeeding charge. Commercial or 50 percent straight dynamite is used in this operation. It is effective, however, only in moist soils, particularly in swamps where the ground is covered by several inches of water. If more than one line of charges is required to obtain a wide ditch, each line is primed. The primed hole is overcharged 1 or 2 pounds.

(2) *Electrical method.* Any high explosive may be used in ditching by the electrical method which is effective in all soils except sand, regardless of moisture content. Each charge is primed with an electric cap and the caps are connected in series. All charges are fired simultaneously.

(3) *Detonating cord method.* In this ditching method any high explosive may be used. It is effective in any type of soil, except sand, regardless of moisture content. Each charge is primed with detonating cord and connected to a truck line.

96. Introduction

In military operations, construction jobs occur in which demolitions may be employed to advantage. Among these jobs are land clearing, which includes stump and boulder removal, and quarrying. The explosives commonly used are military dynamite and detonating cord. The quantity of explosive used is generally calculated by rule of thumb. Charges are generally placed in boreholes, in the ground under or at the side of the target, in the target, or on top of the target. Practically all charges are tamped in some way; some are mudcapped, which is a light form of tamping.

97. Stump Removal

In certain military operations it may be necessary to remove stumps as well as trees. Stumps are of two general types, tap- and lateral-rooted. Military dynamite is best suited for stump removal. A rule of thumb is to use 1 pound per foor of diameter for dead stumps and 2 pounds per foot for live stumps; and if both tree and stump are to be removed, to add 50 percent of the amount of explosive. Measurements are taken at points 12 to 18 inches above the ground (fig. 69).

a. Taproot Stumps. For taproot stumps, one method is to bore a hole in the taproot below the level of the ground (fig. 67). For best results, tamp the charge. The best method is to, place charges on both sides of the taproot to obtain a shearing effect.

b. Lateral-root Stumps. In blasting lateral root stumps, drill a hole as shown in figure 69. Place the charge as nearly possible under the center of the stump and at a depth approximately equal to the radius of the stump base. If for some reason the root formation cannot be determined, assume that it is the lateral type and proceed accordingly.

98. Boulder Removal

In the building of roads and airfields or other military construction, boulders can be removed by blasting. The most practical methods are snakeholing, mudcapping, and blockholing.

a. Snakeholing Method. By this method, a hole large enough to hold the charge is dug under the boulder. The explosive charge is packed under and against the boulder as shown in figure 70. It may be primed electrically or nonelectrically.

b. Mudcapping Method. For surface or slightly unbedded boulders, the mudcapping method is very effective. The charge is placed on top or against the side of the boulder and covered with 10 to 12 inches of mud or clay (fig. 70). It may be primed electrically or nonelectrically.

c. Blockholing Method. This method is very effective on boulders lying on the surface or slightly embedded in the earth. A hole is drilled on top of the boulder deep and wide enough to hold the amount of explosive indicated in table X. The charge is then primed and tamped into the borehole (fig. 70). An electric or nonelectric blasting cap may be used.

Table X. Charge Size for Blasting Boulders

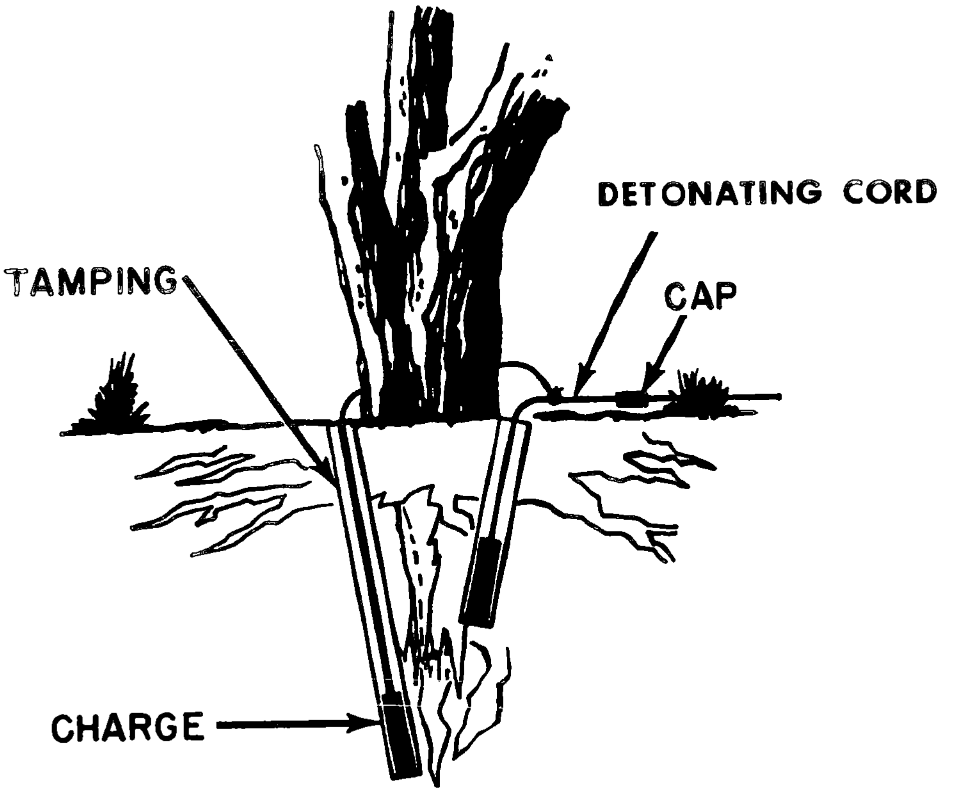
Boulder diameter (ft)	Pounds of explosive required		
	Blockholing	Snakeholing	Mudcapping
1½	⅛	½	1
2	⅛	½	1½
3	¼	¾	2
4	⅜	2	3½
5	½	3	6

99. Springing Charges

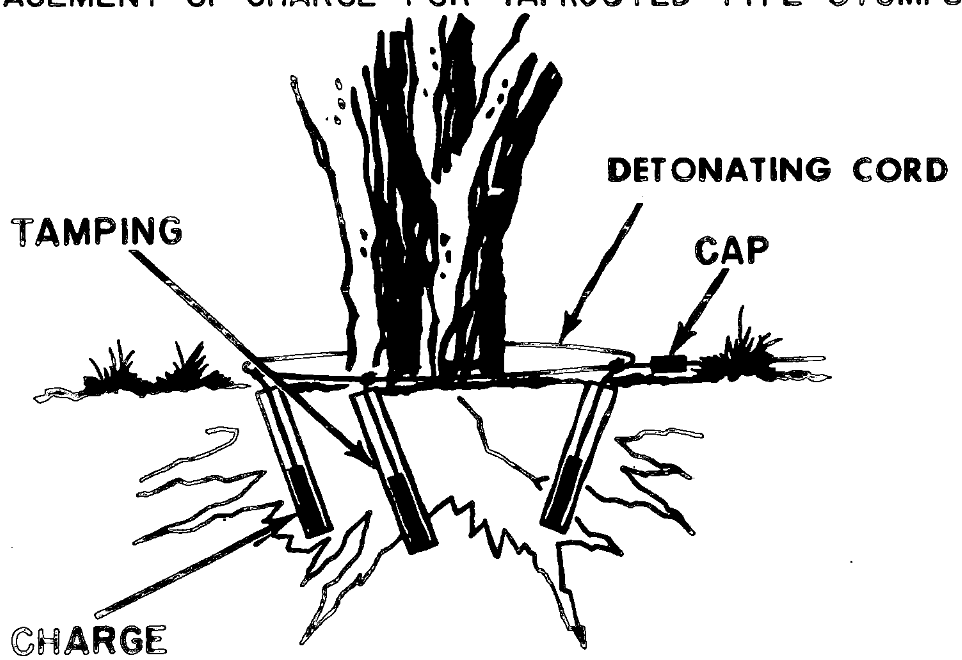
a. Definition and Method. A springing charge is a comparatively small charge placed in the bottom of a drilled borehole and exploded to form an enlarged chamber for placing a larger charge. At times two or more springing charges in succession may be needed to make the chamber large enough for the final charge. Under these conditions at least 30 minutes must be allowed for the boreholes to cool between firing and placing successive charges.

b. Detonating Cord Wick. This is several strands of detonating cord taped together and used to enlarge boreholes in soils. One strand generally widens the diameter of the hole about 1 inch.

(1) A hole is made by driving a steel rod approximately 2 inches in diameter into the ground to the depth required. According to the rule of thumb, a hole 10 inches in diameter requires 10 strands of detonating cord. These must extend the full length of the hole and be taped or tied together into a "wick" to give optimum results. The wick may be placed into the hole by an inserting rod or some field ex-



PLACEMENT OF CHARGE FOR TAPROOTED TYPE STUMPS



PLACEMENT OF CHARGE FOR LATERAL-ROOTED TYPE STUMPS

Figure 69. Stump blasting charges.

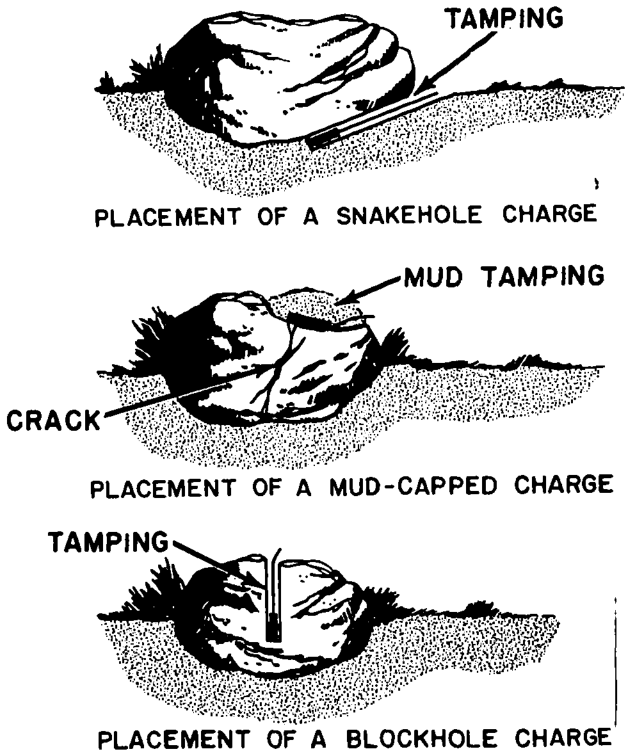


Figure 70. Boulder blasting methods.

pedient. Firing may be done electrically or nonelectrically. An unlimited number of wicks may be fired at one time by connecting them by a detonating cord ring main or main line.

(2) The best results from the use of the detonating cord wick are obtained in hard soil. If successive charges are placed in the holes, excess gases must be burned out and the hole inspected for excessive heat.

c. Limited Use. Springing charges are used only if the soil is too hard for hand operated earth augers or if motorized earth augers are not available.

100. Quarrying

Quarrying is the extraction of rock in the natural state. Military quarries, generally of the open face type, are usually developed by the single bench method. See TM 5-332 for complete detailed information on quarry operations.

CHAPTER 4
DEMOLITION ORDERS AND PROJECTS

Section I. TARGET RECONNAISSANCE AND DEMOLITION ORDERS

101. Concept

Thus far, this manual has been concerned with methods and techniques in the selection, calculation, priming, placement, and firing of explosives on such materials as steel, concrete, wood, and stone and in earth. This chapter, however, deals with the problems of applying these techniques to the conduct of demolitions projects.

102. Reconnaissance to Develop Demolition Plan

a. Information Required. Thorough reconnaissance is necessary before an effective plan may be made to demolish a target, as it provides information in all areas related to the project. For the demolition of bridges and culverts and road craters, the following data is provided by reconnaissance.

(1) Situation map sketch (fig. 71) showing the relative position of the objects to be demolished, the surrounding terrain features, and the coordinates of the objects keyed to existing maps.

(2) Side-view sketch of the demolition object. If, for example a bridge is to be blown, a sketch showing the overall dimensions of critical members is necessary (fig. 72).

(3) Cross section sketches, with relatively accurate dimensions of each member to be cut (fig. 72).

(4) A bill of explosives, showing the quantity and kind required.

(5) Sketch of the firing circuits.

(6) List of all equipment required for the demolition.

(7) List of all unusual features of the site.

(8) Estimate of time and labor required to bypass the site.

(9) Estimate of time and labor required for the demolition.

(10) Estimate and sketch of security details required.

b. Demolition Reconnaissance Record. DA Form 2203–R (Demolition Reconnaissance Record) (fig. 73), together with appropriate sketches, is used to report the reconnaissance of a military demolitions project. This form and the actions listed in *a* above are intended primarily for road and bridge demolition. They are also partially applicable to the demolition of almost any other object. In certain instances, the report may require a security classification. The form will be reproduced locally on 8- by 10½-inch paper.

103. Demolition Orders

a. Purpose. Three commanders are usually involved in the execution of a demolition project. These are the tactical commander with over-all responsibility and authority to order the firing of the demolition, the commander of the demolition guard, and the commander of the demolition firing party. To assist the commanders in the execution of their responsibilities, two demolition orders are used. These are format, figure 74 (Orders to the Demolition Guard Commander) and DA Form 2050–R, figure 75 (Orders to the Commander, Demolition Firing Party). The procedures that follow are in accord with the agreement between the armed forces of NATO nations and will be complied with by Department of the Army units.

b. Procedures. Each authorized commander, or the tactical commander referred to in *a* above, will—

(1) Establish the requirement and allow the responsibility for a demolition guard and a demolition firing party.

(2) Establish a clear cut channel whereby the order to fire the demolition is transmitted from himself to the commander of the demolition guard and thereby to the

SITUATION MAP SKETCH.(INCLUDE PRINCIPAL TERRAIN FEATURES; IMMEDIATE AVENUES OF APPROACH; OBSERVATION AND COVER; MAP COORDINATES).

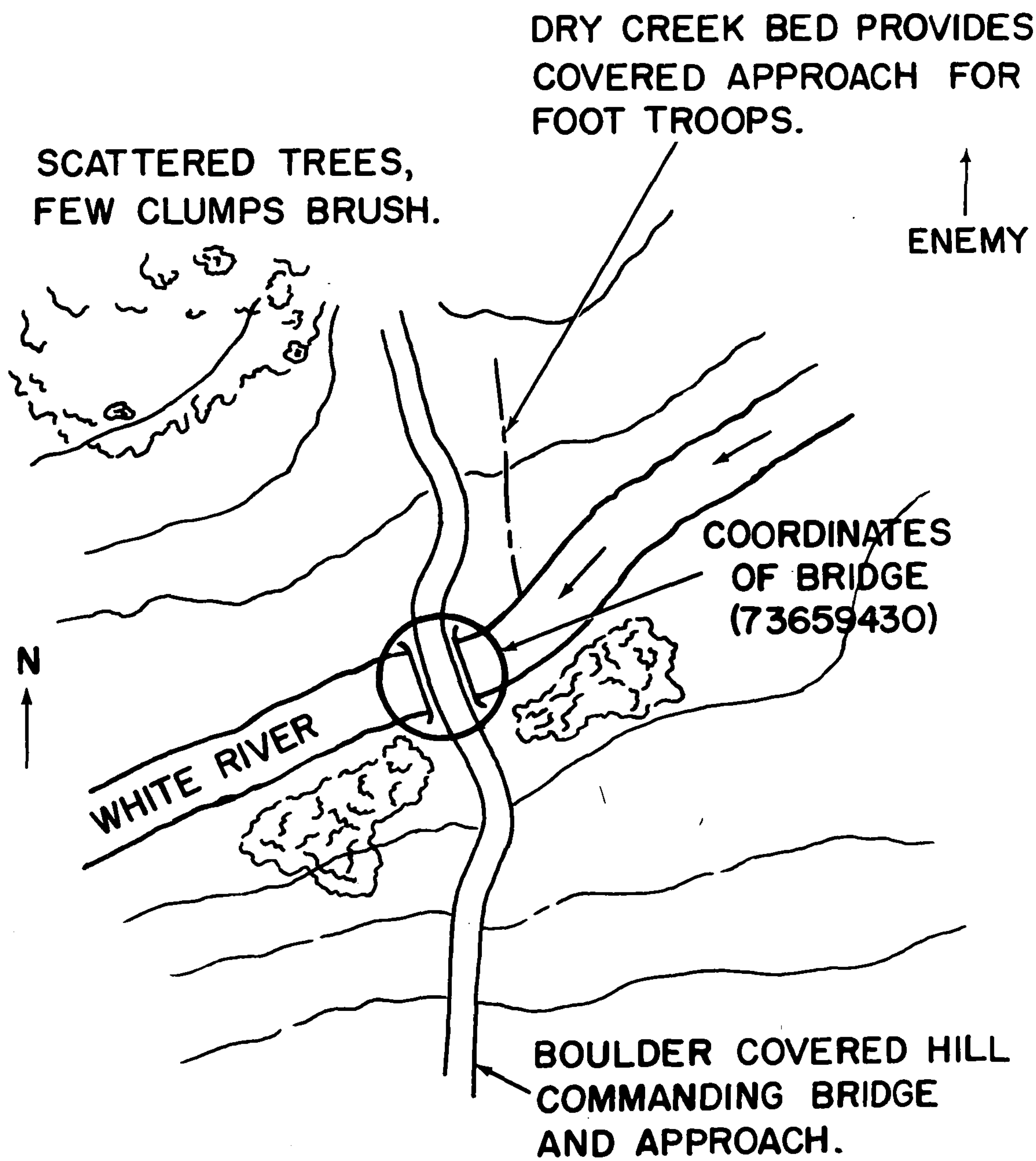


Figure 71. Situation map sketch.

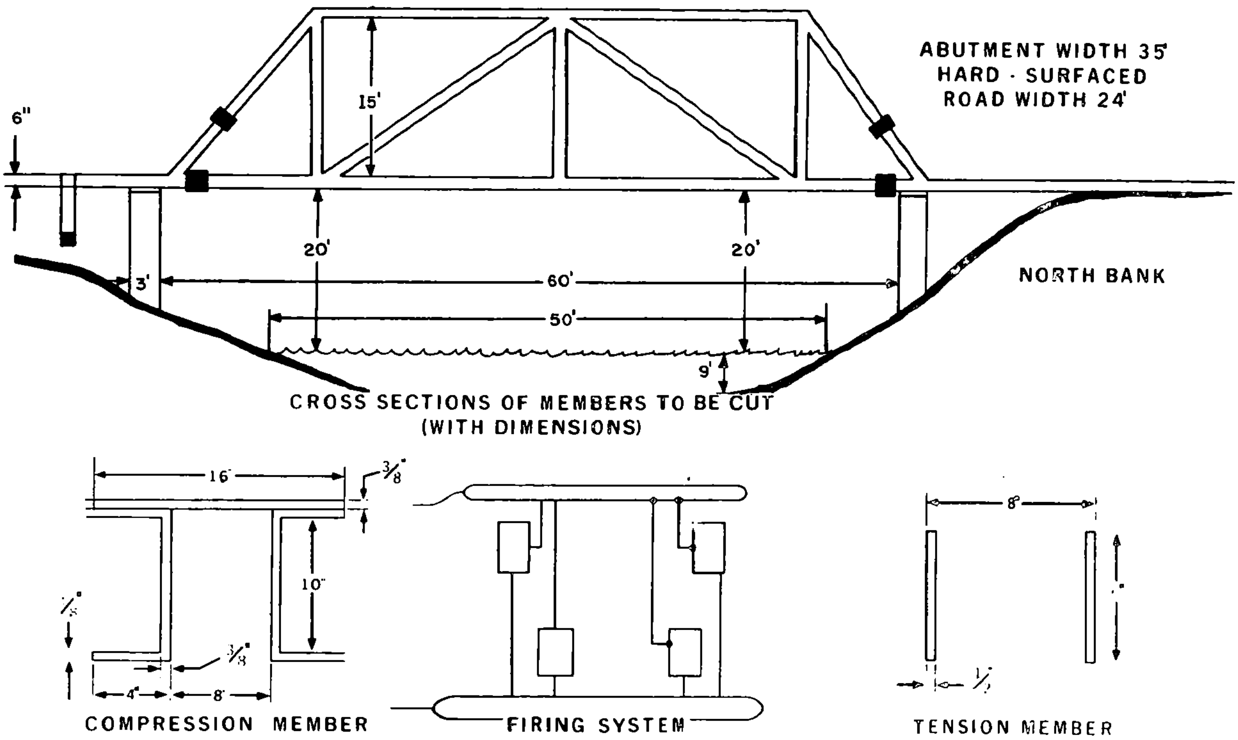


Figure 72. Drawing of object to be demolished.

commander of the demolition firing party. In the event that no demolition guard is required, this channel must be established between the authorized commander and the commander of the demolition firing party.

(3) Insure that this channel is known and understood by all concerned, and that positive and secure means of transmitting the order to fire are established.

(4) Specify the conditions for executing the demolition by completing part V of "Orders to the Commander, Demolition Firing Party," and part IV of the "Orders to the Demolition Guard Commander."

c. Orders to the Demolition Guard Commander. The authorized commander completes and signs this form. The order is written in seven parts, each of which is self-explanatory.

d. Orders to the Commander, Demolition Firing Party. In addition to those items listed in *b* above, the authorized commander designates the unit or individual responsible for the preparation of these orders. This unit or individual will complete and sign parts I through III and pass the order to the commander of the demolition firing party. Part IV will be completed upon detonation of the demolition (fig. 75).

e. Definitions. The states of readiness (*safe and armed*) referred to in part I of the Order to the Commander, Demolition Firing Party, and in part II of the Order to the Demolition Guard Commander, are described as follows:

(1) "1 (*Safe*)." The explosive charges are prepared and securely fixed to the target and are safe against premature firing. All firing circuits and accessories have been checked, are in proper operating condition, and are ready to be attached to charges. If detonating cord is used it may be attached to demolition charges; however, detonators will not be attached to detonating cord until the state of readiness is changed to "armed."

(2) "2 (*Armed*)." The demolition is ready for immediate firing. The risk of premature detonation is accepted.

f. Disposition of Orders. After the demolition has been fired, one copy of the orders will be retained by the headquarters of the issuing authority and one by the commander of the demolition firing party.

DEMOLITION RECONNAISSANCE RECORD
(FM 5-25)

SECTION I - GENERAL

1. FILE NO.	2. DML RECON REPORT NO.	3. DATE	4. TIME
411	1	21 JUNE 63	2100

5.	NAME	GRADE	ORGANIZATION
RECON ORDERED BY	JOHN J. SHUBA	CAPT.	954 ENGR BN
6. PARTY LEADER	JOE C. GAY	SFC	RECON SEC

7. MAP REFERENCE STANTON 1:25,000 SHEET NO 5578 IV SE

8. SITE AND OBJECT	9. TIME OBSERVED	10. LOCATION
STEEL TRUSS BRIDGE ACROSS WHITE RIVER ON HWY 1	2200	73659430

11. GENERAL DESCRIPTION SINGLE SPAN STEEL TRUSS CONSTRUCTION, LENGTH OF SPAN 60 FT. WIDTH OF BRIDGE 24 FT. HEIGHT OF TRUSS 15 FT. HEIGHT OF BRIDGE ABOVE WATER 20 FT. CONCRETE ABUTMENTS 35 FT WIDE.

12. NATURE OF PROPOSED DEMOLITION ROTATION METHOD. CUT UPPER AND LOWER CHORD ON BOTH ENDS OF TRUSS ON THE UPSTREAM SIDE OF THE BRIDGE. DESTROY SOUTH SHORE ABUTMENT.

SECTION II - ESTIMATES*

EXPLOSIVES REQUIRED

a. TYPES	b. POUNDS	c. CAPS		d. DETONATING CORD	e. FUSE LIGHTERS
		Electric	Nonelectric		
TNT CRATERING CHG	20 LBS 6 - 40 LB CHGS	4	0	500 FT	0

14. EQUIPMENT REQUIRED

1 — 2½ TON TRUCK
1 — SQUAD DEMO SET.
7 EXTRA REELS OF FIRING WIRE.

15. PERSONNEL AND TIME REQUIRED	PERSONNEL	TIME
	1 SQUAD	1 HR

SECTION III - REMARKS

16. UNUSUAL FEATURES OF SITE

NONE

17. LABOR AND TIME ESTIMATED REQUIRED FOR BYPASS

*Determine availability of Items 13, 14, and 15 before reconnaissance.

NOTE: Attach sketches as indicated in Figures 71 and 72, FM 5-25.

DA FORM 2203-R, 1 Sep 63 Previous edition of this form is obsolete.

Figure 73. Demolitions reconnaissance record (DA Form 2203-R).

CLASSIFICATION

Serial No.___________________Security Classification___________

ORDERS TO THE DEMOLITION GUARD COMMANDER

Notes:
1. This form will be completed and signed before it is handed to the Commander of the Demolition Guards.
2. In completing the form, all spaces must either be filled in or lined out.
3. The officer empowered to order the firing of the demolition is referred to throughout as the "Authorized Commander".

From___________________________To_____________________________

PART I - PRELIMINARY INSTRUCTIONS

1.a. Description of target____________________________________

b. Location:

Map Name and Scale_______________Sheet No.______________

Grid Reference________________________

c. Codeword or codesign (if any) of demolition target._________

2. The Authorized Commander is__________________________________ (give appointment only). If this officer should delegate his authority, you will be notified by one of the methods shown in paragraph 4, below.

3. The DEMOLITION FIRING PARTY has been/will be provided by_____________________

4. All messages, including any codewords or codesign (if any) used in these orders, will be passed to you by:

a. Normal command wireless net, or

b. Special liaison officer with communications direct to the Authorized Commander, or

CLASSIFICATION

Figure 74. Orders to the Demolition Guard Commander.

c. Telephone by the Authorized Commander, or

d. The Authorized Commander personally, or

e. ____

(Delete those NOT applicable)

Note: All orders sent by message will be prefixed by the codeword or codesign (if any) at paragraph 1.c., and all such messages must be acknowledged.

Figure 74—Continued.

PART II - CHANGING STATES OF READINESS

5. The demolition will be prepared initially to the State of Readiness_______________by___________hours on_________(date).

6. On arrival at the demolition site, you will ascertain from the commander of the demolition firing party the estimated time required to change from State "1" (SAFE) to State "2" (ARMED). You will ensure that this information is passed to the Authorized Commander and is acknowledged.

7. Changes in the State of Readiness from State "1" (SAFE) to State "2" (ARMED) or from State "2" to State "1" will be made only when so ordered by the Authorized Commander. However, the demolition may be ARMED in order to accomplish emergency firing when you are authorized to fire it on your own initiative.

8. A record of the changes in the State of Readiness will be entered by you in the table below, and on the firing orders in possession of the commander of the demolition firing party.

State of Readiness ordered "1" (SAFE) or "2" (ARMED)	Time & date change to be completed	Authority	Time & date of receipt of order

Note: If the order is transmitted by an officer in person, his signature and designation will be obtained in the column headed "Authority".

9. You will report completion of all changes in the State of Readiness to the Authorized Commander by the quickest means.

PART III - ORDERS FOR FIRING THE DEMOLITION

10. The order for firing the demolition will be passed to you by the Authorized Commander.

Figure 74—Continued.

NATO - UNCLASSIFIED (Cont'd)

PART III - ORDERS FOR FIRING THE DEMOLITION

11. On receipt of this order you will immediately pass it to the commander of the demolition firing party on his demolition Orders form ("Orders to the Commander of the Demolition Firing Party").

12. After the demolition has been fired you will report the results immediately to the Authorized Commander.

13. In the event of a misfire or only partially successful demolition you will give the firing party protection until such time as it has completed the demolition and report again after it has been completed.

NATO - UNCLASSIFIED (Cont'd)

Figure 74—Continued.

NATO - UNCLASSIFIED

PART IV - EMERGENCY FIRING ORDERS

Notes: 1. One sub-paragraph of paragraph 14 must be deleted.

2. The order given herein can only be altered by the issue of a new form, or, in emergency by the appropriate order (or codeword if used) in Part V.

14.a. You will order the firing of the demolition only upon the order of the Authorized Commander.

OR

b. If the enemy is in the act of capturing the target, and/or munition, you will order the firing of the demolition on your own initiative.

PART V - CODEWORDS (IF USED)

	Action to be taken	Codeword (if used)
a.	Change State of Readiness from "1" to "2" (See paragraph 7)	
b.	Change State of Readiness from "2" to "1" (See paragraph 7)	
c.	Fire The Demolition (see paragraph 10)	
d.	Paragraph 14a is now cancelled. You are now authorized to fire the demolition if the enemy is in the act of capturing it.	

NATO - UNCLASSIFIED

Figure 74—Continued.

PART IV - EMERGENCY FIRING ORDERS

e.	Paragraph 14b is now cancelled. You will order the firing of the demolition only upon the order of the Authorized Commander.	Codeword (if used)
f.	Special authentication instructions, if any.	

PART VI

Signature of officer issuing these orders____________

Name (printed in capital letters)____________________

Rank________________Appointment____________________

Time of issue________hours,___________________(date).

Figure 74—Continued.

PART VII - DUTIES OF THE COMMANDER OF THE DEMOLITION GUARD

15. You are responsible for:-

    a. Command of the demolition guard and the demolition firing party.

    b. The safety of the demolition from enemy attack, capture, or sabotage.

    c. Control of traffic and refugees.

    d. Giving the orders to the demolition firing party in writing to change the state of readiness.

    e. Giving the order to the demolition firing party in writing to fire the demolition.

    f. After the demolition, reporting on its effectiveness to the Authorized Commander.

    g. Keeping the Authorized Commander informed of the operational situation at the demolition site.

16. You will acquaint yourself with the orders issued to the Commander of the Demolition Firing Party and with the instructions given by him.

17. The Demolition Guard will be so disposed as to ensure at all time complete all-round protection of the demolition against all types of attack or threat.

18. The Commander of the Demolition Firing Party is in technical control of the demolition. You will agree with him on the site of your Headquarters and of the firing point. These should be together whenever practicable. When siting them you must give weight to the technical requirements of being able to view the demolition and have good access to it from the firing point.

Figure 74—Continued.

PART VII - DUTIES OF THE COMMANDER

OF THE DEMOLITION GUARD

19. You will nominate your deputy forthwith and compile a seniority roster. You will ensure that each man knows his place in the roster, understands his duties and knows where to find this form if you become a casualty or are unavoidably absent. The seniority roster must be made known to the Commander of the Demolition Firing Party.

20. Once the state of readiness "2 ARMED" has been ordered, either you or your deputy must always be at your Headquarters so that orders can be passed on immediately to the Commander of the Demolition Firing Party.

Figure 74—Continued.

SECURITY CLASSIFICATION

ORDERS TO THE COMMANDER, DEMOLITION FIRING PARTY	SERIAL NUMBER

NOTE: Parts I, II and III will be completed and signed before this form is handed to the commander of the Demolition Firing Party. Paragraphs 4 and 5 can only be altered by the authority issuing these orders. In such cases a new form will be issued and the old one destroyed.

FROM:	TO:

PART I - ORDERS FOR PREPARING AND CHARGING THE DEMOLITION TARGET

1a. DESCRIPTION

b. LOCATION			c. CODE WORD OF DEMOLITION TARGET (If any)
MAP NAME AND SCALE	SHEET NO.	GRID REFERENCE	

d. ATTACHED PHOTOGRAPHS AND SPECIAL TECHNICAL INSTRUCTIONS

2. THE DEMOLITION GUARD IS BEING PROVIDED BY (Unit)

3. YOU WILL PREPARE AND CHARGE THE DEMOLITION TARGET TO THE STATE OF READINESS ______ BY ______ HOURS ON (Date)______. ANY CHANGES MAY ONLY BE MADE ON THE ORDER OF THE ISSUING AUTHORITY, OR BY THE OFFICER DESIGNATED IN PARAGRAPH 4d AND WILL BE RECORDED BELOW.

STATE OF READINESS ORDERED "1(SAFE)" or "2(ARMED)"	TIME AND DATE CHANGE TO BE COMPLETED	AUTHORITY	TIME AND DATE OF RECEIPT OF ORDER

NOTE: All orders received by message will be verified by the code word at Paragraph 1c. If the order is transmitted by an officer in person, his signature and designation will be obtained in the Column headed "Authority".

PART II - ORDERS FOR FIRING

NOTE: The officer issuing these orders will strike out the subparagraphs of Paragraphs 4 and 5 which are not applicable. When there is a demolition guard, Paragraph 4 will always be used and Paragraph 5 will always be struck out.

4a. YOU WILL FIRE THE DEMOLITION AS SOON AS YOU HAVE PREPARED IT.
b. YOU WILL FIRE THE DEMOLITION AT ______ HOURS ON (Date)______.
c. YOU WILL FIRE THE DEMOLITION ON RECEIPT OF THE CODE WORD ______.
d. YOU WILL FIRE THE DEMOLITION WHEN THE OFFICER WHOSE DESIGNATION IS ______ ______ HAS SIGNED PARAGRAPH 8 BELOW.

EMERGENCY FIRING ORDERS (ONLY applicable when there is NO demolition guard)

5a. YOU WILL NOT FIRE THE DEMOLITION IN ANY CIRCUMSTANCES EXCEPT AS ORDERED IN PARAGRAPH 4 ABOVE.
b. YOU WILL FIRE THE DEMOLITION ON YOUR OWN INITIATIVE IF THE ENEMY IS IN THE ACT OF CAPTURING IT.

DA FORM 2050-R, 1 NOV 57 SECURITY CLASSIFICATION

Figure 75. Orders to the Commander, Demolition Firing Party (DA Form 2050-R).

SECURITY CLASSIFICATION

PART III - ORDERS FOR REPORTING			
6. AFTER FIRING THE DEMOLITION YOU WILL IMMEDIATELY REPORT RESULTS TO THE OFFICER WHO ORDERED YOU TO FIRE. IN THE EVENT OF A PARTIAL FAILURE YOU WILL WARN HIM, AND IMMEDIATELY CARRY OUT THE WORK NECESSARY TO COMPLETE THE DEMOLITION			
7. FINALLY, YOU WILL IMMEDIATELY REPORT THE RESULTS TO YOUR UNIT COMMANDING OFFICER (See Paragraph 13.)			
SIGNATURE OF OFFICER ISSUING THESE ORDERS	NAME (In capitals) DESIGNATION	TIME OF ISSUE	DATE OF ISSUE
PART IV - ORDER TO FIRE			
8. BEING EMPOWERED TO DO SO, I ORDER YOU TO FIRE NOW THE DEMOLITION DESCRIBED IN PARAGRAPH 1.			
SIGNATURE	NAME (In capitals) DESIGNATION	TIME	DATE

PART V - GENERAL INSTRUCTIONS (Read These Instructions Carefully)

9. YOU ARE IN TECHNICAL CHARGE OF THE PREPARATION, CHARGING AND FIRING OF THE DEMOLITION TARGET DESCRIBED. YOU WILL NOMINATE YOUR DEPUTY FORTHWITH AND COMPILE A SENIORITY ROSTER OF YOUR PARTY. YOU WILL INSURE THAT EACH MAN KNOWS HIS PLACE IN THE ROSTER, UNDERSTANDS THESE INSTRUCTIONS, AND KNOWS WHERE TO FIND THIS FORM IF YOU ARE HIT OR UNAVOIDABLY ABSENT. YOU WILL CONSULT WITH THE COMMANDER OF THE DEMOLITION GUARD ON THE SITING OF THE FIRING POINT.

10. YOU MUST UNDERSTAND THAT THE COMMANDER OF THE DEMOLITION GUARD (where there is one) IS RESPONSIBLE FOR:
    a. OPERATIONAL COMMAND OF ALL THE TROOPS AT THE DEMOLITION SITE. (You are therefore under his command.)
    b. PREVENTING THE CAPTURE OF THE DEMOLITION SITE, OR INTERFERENCE BY THE ENEMY WITH DEMOLITION PREPARATIONS.
    c. CONTROLLING ALL TRAFFIC AND REFUGEES.
    d GIVING YOU THE ORDER TO CHANGE THE STATE OF READINESS FROM "1(SAFE)" TO "2(ARMED)" OR BACK TO "1(SAFE)" AGAIN. YOU WILL INFORM HIM OF THE TIME REQUIRED FOR SUCH A CHANGE.
    e. PASSING TO YOU THE ACTUAL ORDER TO FIRE.

11. WHEN THERE IS NO DEMOLITION GUARD AND YOU ARE INSTRUCTED IN PARAGRAPH 4 TO ACCEPT THE ORDER TO FIRE FROM SOME PARTICULAR OFFICER, IT IS IMPORTANT THAT YOU ARE ABLE TO IDENTIFY HIM.

12. IF YOU GET ORDERS TO FIRE, OTHER THAN THOSE LAID DOWN IN PARAGRAPH 4, YOU SHOULD REFER THEM TO THE DEMOLITION GUARD COMMANDER OR, IF THERE IS NO DEMOLITION GUARD COMMANDER, TO YOUR IMMEDIATE SUPERIOR. IF YOU CANNOT DO THIS, YOU WILL ONLY DEPART FROM YOUR WRITTEN INSTRUCTIONS WHEN YOU ARE SATISFIED AS TO THE IDENTITY AND OVERRIDING AUTHORITY OF WHOEVER GIVES YOU THESE NEW ORDERS, AND YOU WILL GET HIS SIGNATURE IN PARAGRAPH 8 WHENEVER POSSIBLE.

13. THE REPORT TO YOUR UNIT COMMANDING OFFICER, AS CALLED FOR IN PARAGRAPH 7, SHOULD CONTAIN THE FOLLOWING INFORMATION (where applicable):
    a. IDENTIFICATION REFERENCE OF DEMOLITION.
    b. MAP REFERENCE.
    c. TIME AND DATE WHEN DEMOLITION WAS FIRED.
    d. EXTENT OF DAMAGE ACCOMPLISHED, INCLUDING:
        ESTIMATED WIDTH OF GAP) IN CASE OF A BRIDGE
        NUMBER OF SPANS DOWN)
        SIZE AND LOCATION OF CRATERS IN A LOAD OR RUNWAY
        MINES LAID.
    e. SKETCH SHOWING EFFECT OF DEMOLITION.

SECURITY CLASSIFICATION

Figure 75—Continued.

Section II. TECHNIQUES COMMON TO MOST DEMOLITIONS

104. Types of Military Demolitions

There are three types of demolitions applicable to tactical situations—reserved, deliberate, and hasty.

a. Reserved Demolitions. These are specifically controlled at whatever level of command, either because they are a vital part of the tactical or strategic plan, or because the target is an extremely important military objective. Reserved demolitions are usually "ready and waiting."

b. Deliberate Demolitions. Deliberate demolitions are used when enemy interference during preparations is unlikely and there is sufficient time for thorough reconnaissance and careful preparation. Deliberate preparation permits economy in the use of explosives, since time permits accurate calculation and positive charge placement. In deliberate demolition, the destruction is carried to the point where it is more economical for the enemy to replace than repair the facility or equipment. Ordinarily, this situation exists only in rear areas where demolitions are prepared in anticipation of a breakthrough by the enemy.

c. Hasty Demolitions. Hasty demolitions are used when time is limited and economy of explosives is secondary to speed. In all cases, common sense and good judgment must be exercised to prevent waste. In the preparation of demolition projects in forward areas where a surprise raid by hostile forces is possible, a priority should be given to each charge. Although this procedure is relatively time consuming, it causes maximum damage to the project in relation to the time required, even though enemy interference might prevent completion of the job. Each charge is primed as it is placed; for if charges are all placed first and then primed afterwards, it is possible that enemy interference prior to the act of priming might stop the work before any damage is done. The use of dual detonating cord ring main lines and branch lines is recommended for all frontline demolition projects.

105. Nuclear Weapons Demolitions

Atomic demolition munitions (ADM) may be effectively employed to create obstacles and to destroy and deny military facilities or installations. They have a capability to create large radioactive craters with little preparatory effort. The residual radiation and fallout hazards require consideration; however, the use of small yields minimizes the fallout hazard and area of residual contamination. The ADM, like conventional hand-placed charges, has a primary advantage of no delivery error, which permits the use of minimum yield for a given target. This is of particular importance in producing craters or for destruction through cratering effects since the radius of cratering effects of atomic weapons is relatively small in comparison with other effects.

106. Demolition at Vulnerable Points

Structures, facilities, and equipment are destroyed at their most vulnerable points so that a minimum of explosive will cause the greatest damage. For example, it is more practical to destroy a large railroad bridge than to use the same amount of explosive to destroy railroad track.

107. Supplementing Demolition Obstacles

Nuisance mining and chemical contaminants are a very potent means of increasing the effects of demolition projects. The area to be mined should include the facility to be destroyed, the ground where a replacement structure or remedial work will likely be performed, working party bivouacs, and alternate sites. Thus, for a demolished bridge, the dropped spans and abutments should be mined to impede removal or recovery; suitable sites for a floating bridge or ford should be mined to prevent ready use; and locations likely to be selected for material storage, equipment parks, or bridge unit bivouacs should also be well mined and booby-trapped.

108. Extent of Demolition

a. Complete Demolition Rare. Complete demolition of a bridge results in leaving nothing of the old bridge suitable for use in a new bridge. Debris is left on the site where its removal will require much hazardous work before any kind of crossing can be installed. However, when enough demolition is accomplished to force the enemy to select another site for a temporary bridge as a substitute for the damaged bridge, further demolition is unnecessary. Too, a permanent structure is not likely to be replaced in kind during wartime. Where the terrain is such, however, that the existing bridge site is needed for a new structure, even a temporary one, demolition in greater proportions may be justified.

b. Partial Demolition.

(1) *Method.* Bridges are generally demolished to create obstacles that delay the enemy. This seldom requires complete destruction. Unless a denial operation is in effect, the demolition method chosen should permit the economical reconstruction of the bridge by friendly troops at a later date. Frequently the necessary delay can be obtained by only blasting a gap too long to be spanned by the prefabricated bridging available to the enemy. This gap should be located where the construction of an intermediate support is difficult or impossible. A high and relatively slender bridge component may be demolished by cutting one side so that the entire structure topples into a mass of broken and twisted material. The destruction of massive bridge components requires large expenditures of explosive, time, equipment, and effort that may not be profitable. In many cases, on major bridges, the demolition of any component that can easily be replaced may not be justified.

(2) *Factors determining the extent of destruction.* Factors that determine the extent of destruction needed for a project are as follows:

(*a*) The tactical and strategical situations that indicate the length of time the enemy must be delayed; the time available for demolition; and the extent of denial to be accomplished.

(*b*) The likelihood that friendly forces may reoccupy the area and require the use of the bridge.

(*c*) The results to be obtained by the expenditure of labor and materials compared with the results that may be obtained elsewhere with the same effort.

(*d*) The manpower, equipment, and kinds and quantities of explosives available.

109. Parts of Fixed Bridges

The ordinary fixed bridge is divided into two main parts: the lower part or substructure, and the upper part or superstructure (fig. 76).

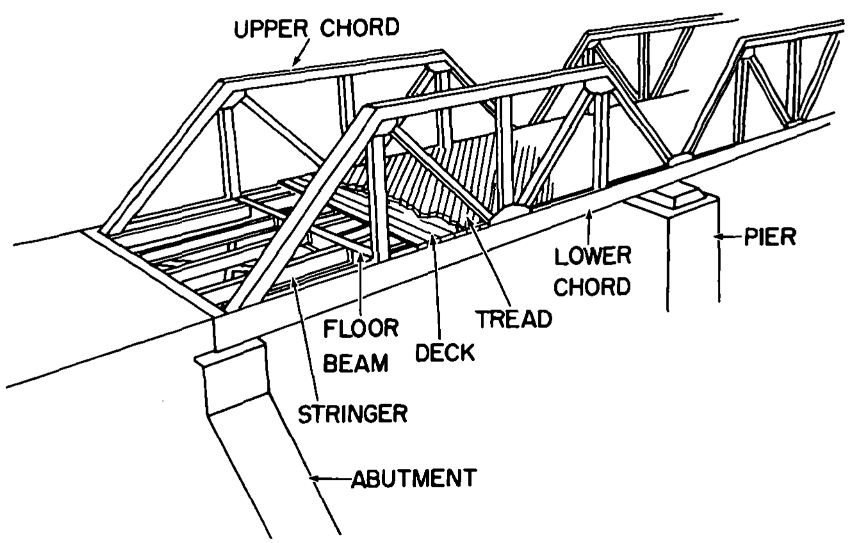


Figure 76. Parts of fixed bridges.

a. Substructure. The substructure consists of the parts of the bridge that support the superstructure. There are two kinds of supports: end supports or abutments, and intermediate supports or piers or bents. The parts of the substructure are—

(1) *Abutment.* The ground supports at the ends of a bridge are called abutments. These may be constructed of concrete, masonry, steel, or timber and may include retaining walls or an end dam.

(2) *Footing.* A footing is that part of any bridge support that rests directly on the ground. It distributes the load over an area wide enough to keep the support from sinking into the ground.

(3) *End dam.* An end dam is a retaining wall of concrete, wood, or other material at the end of a bridge that supports the bank and keeps the approach road from caving in.

(4) *Intermediate support.* An intermediate support is a support placed beneath a bridge between the abutments. It may be a pier of masonry or concrete, cribbing, several pile or trestle bents constructed as a unit, or a single pile or trestle bent.

b. Superstructure. The superstructure includes the flooring, stringers, floor beams, and any girders or trusses that make up the total part of the bridge above the substructure (fig. 76).

(1) *Span.*

(*a*) *Simple.* Simple spans have stringers that extend only from one support to the next.

(*b*) *Continuous.* Continuous spans have beams that extend over two or more spans.

(2) *Truss.*

(*a*) *Lower chord.* The lower chord is the lower member in a panel of a truss that runs parallel to the deck (tension member).

(*b*) *Upper chord.* The upper chord includes the upper members in the panel (compression member).

(3) *Stringers.* Stringers run longitudinally with the bridge and directly support the deck.

(4) *Deck and tread.* The deck is the floor of the bridge and the tread, the top surface material.

110. Planning Bridge Demolitions

a. Structural Characteristics. The demolition of bridges must be carefully planned, as bridges have a great variety of superstructures made of steel, timber, or masonry and various types of substructures. The size and placement of the charge, therefore, depends on the characteristics of the individual bridge structure.

b. General Procedures. Some general procedures apply to most bridge demolition projects; *for example:* if charges are placed under the bridge roadway, special precautions must be taken to insure that the charges will not be shaken loose or initiated by traffic on the bridge. The following general points apply to the demolition of most or all of the bridge structures mentioned and described below.

(1) The careful location of hasty charges, which must be placed first because of possible enemy interruption, makes it possible to include them later on into the deliberate preparation of the bridge.

(2) It is often possible either to economize on the use of explosives or to improve the thoroughness of the demolition by blasting several times rather than only once. When conditions permit, this procedure should be considered.

(3) Tension members are more difficult to repair than compression members, because the latter may sometimes be replaced by cribbing while the former almost always require steel riveting or welding. Thus tension members should be given priority.

(4) When bridges over railways or canals are being destroyed, the demolition should be so planned that any temporary intermediate piers that might be erected to repair the structure must be located where they will block traffic on the railroad or canal.

(5) Any long steel members that require cutting in only one place to demolish the bridge should be further damaged to prevent their ready salvage by recutting or splicing. It is not necessary to cut such members completely in two at other points to accomplish this. A number of small charges properly located will damage the upper flange, the lower flange, and the web, which will make repair difficult and uneconomical. The twisting of such members in

dropping the span and any other feasible method of further destruction should also be considered.

(6) The nature of the terrain under the bridge is of great importance to the success of the demolition. Whenever possible, the weight of the bridge should be used to assist in its own destruction.

111. Destruction of Substructures

a. Concrete and Masonry Abutments.

(1) *Charges in fill behind abutment.* The placing of charges in the fill behind an abutment has the advantages of economy in the use of explosives and of concealment of the charges from the enemy until they are detonated. This method also has its disadvantages, as the charges are difficult to place. Where speed is required, charges are not placed behind the abutment if the fill is known to contain large rocks. If the bridge approach is an embankment, the most practical method may be to place explosive charges in a tunnel driven into the side of the embankment.

(*a*) *Abutments 5 feet or less in thickness and 20 feet or less in height.* Such abutments are demolished by a line of 40-pound cratering charges placed on 5-foot centers in holes 5 feet deep and 5 feet behind the face of the abutment (fig. 77). The first hole is placed 5 feet from one side of the road, and this spacing is continued until a distance of 5 feet or less is left from the last hole to the other side of the road. The formula for computing the number of charges is $N=\frac{W}{5}-1$, where N=number of charges and W the width of the abutment. If the wing walls are strong enough to support a rebuilt or temporary bridge, they too should be destroyed by placing charges behind them in a similar fashion.

(*b*) *Abutments more than 5 feet thick and 20 feet or less in height.* Such abutments are destroyed by breaching charges placed in contact with the back of the abutment (fig. 78). These charges are calculated by means of the breaching formula,

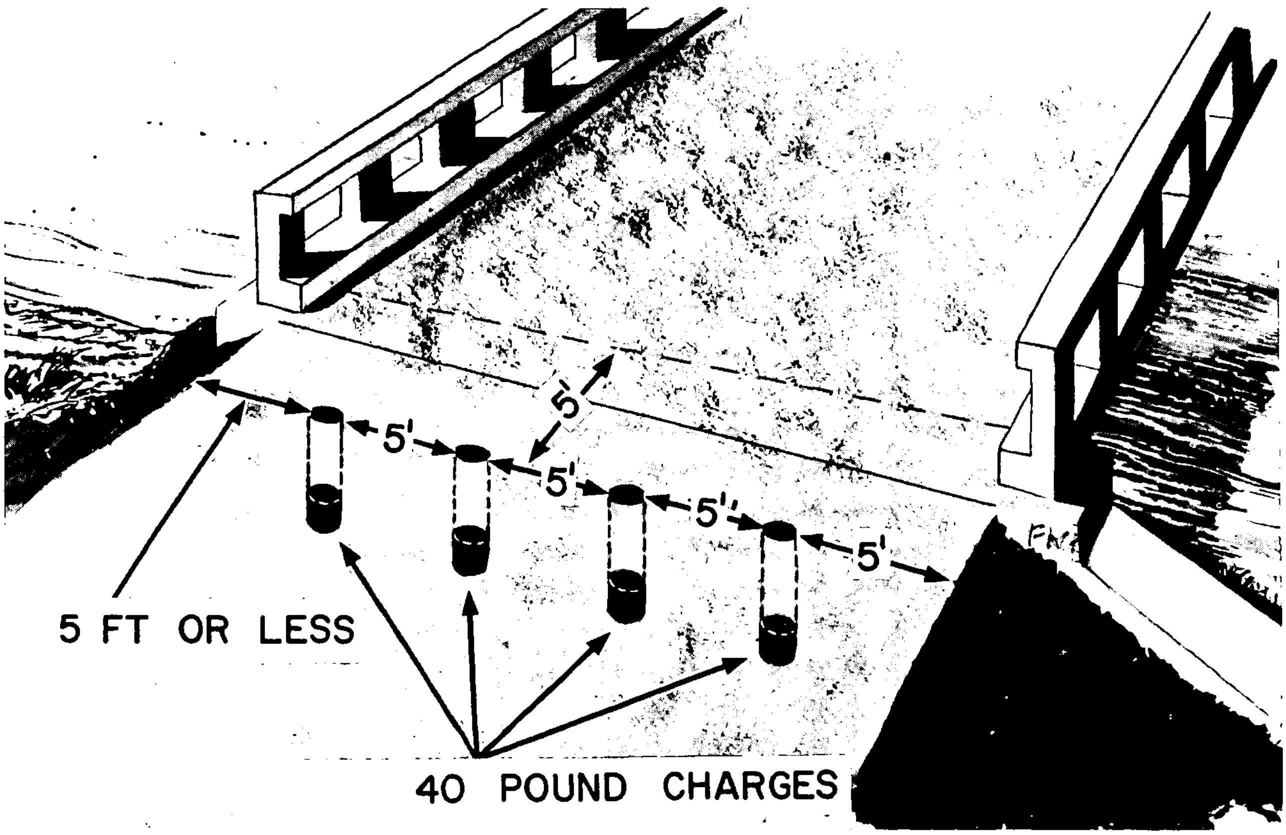


Figure 77. Charges placed in fill behind reinforced concrete abutment 5 feet or less in thickness.

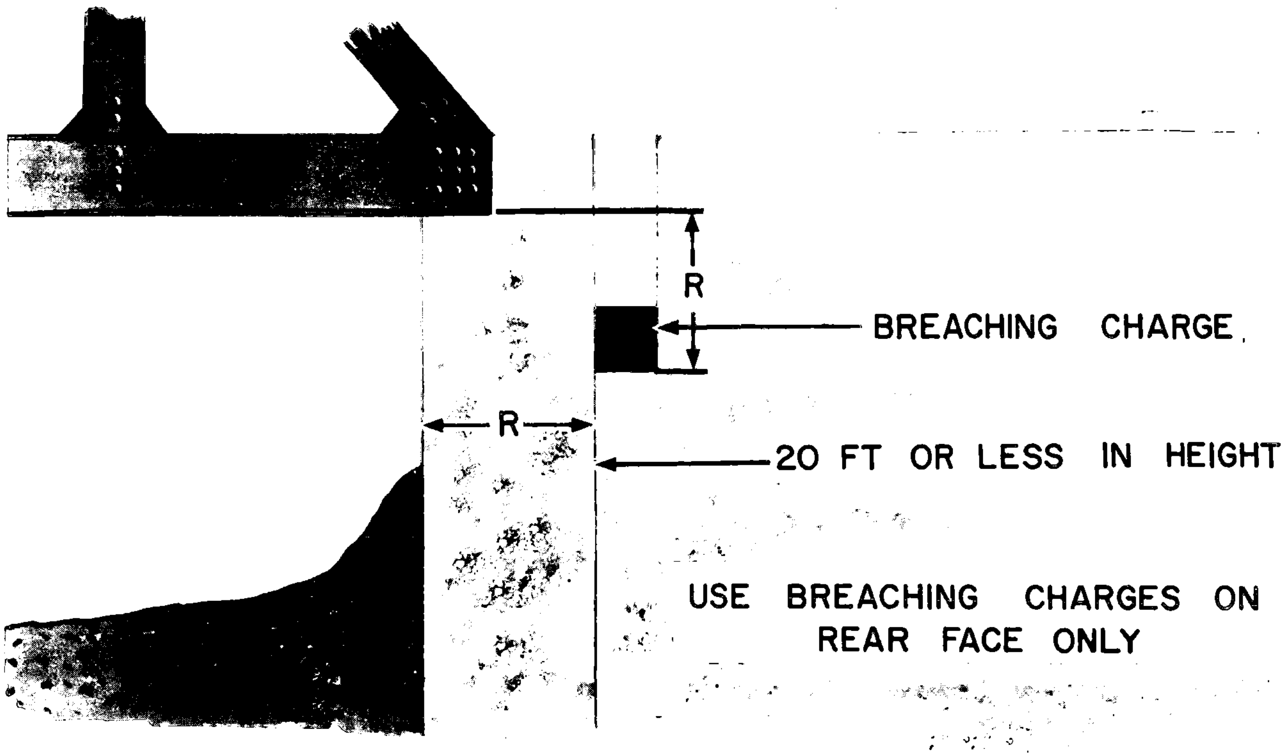


Figure 78. Charges placed in fill behind reinforced concrete abutment more than 5 feet thick.

$P=R^3KC$ (par. 86*a*), using the abutment thickness as the breaching radius R. The charges are placed at a depth equal to or greater than R. The number of charges and their spacing are determined by the formula $N=\frac{W}{2R}$.

(2) *Combination charges.* A combination of external breaching charges and fill charges may be used to destroy abutments more than 20 feet high. Breaching charges placed along the bottom of the abutment face should be fired simultaneously with the charges in the fill behind the abutment. These fill charges may be breaching charges as explained in (1) above, depending on the abutment thickness. This tends to overturn and completely destroy the abutment.

b. Intermediate Supports.

(1) *Effectiveness.* The destruction of one or more intermediate supports of a multispan bridge is usually the most effective method of demolition. The destruction of one support will collapse the spans on each side of it, so that destruction of only alternate intermediate supports is sufficient to collapse all spans. For repair this will require either the replacement of those supports or the construction of long spans.

(2) *Concrete and masonry piers.* Concrete and masonry piers are demolished either by internal or external charges. Internal charges require less explosive than external charges, but because they require a great amount of equipment and time for preparation, they are seldom used unless explosives are scarce or the pier has built in demolition chambers. The number of charges required is calculated by the formula $N=\frac{W}{2R}$ (par. 87*b*). The size of each charge is calculated by the breaching formula, $P=R^3KC$.

(*a*) *Internal charges.* Plastic explosives, dynamite, and other explosives are the most satisfactory for internal charges. All charges of this type should be thoroughly tamped with blunt wooden tamping sticks, *not* with steel bars or tools. If there are no demolition chambers, charges are placed in boreholes, which are blasted by means of shaped charges or drilled with pneumatic or handtools. A 2-inch-diameter borehole holds about 2 pounds of explosive per foot of length or depth. The steel reinforcing bars make drilling in heavily reinforced concrete impractical.

(*b*) *External charges*. External charges may be placed at the base of a pier or higher and spaced not more than twice the breaching radius (par. 86*b*) apart. All external charges should be thoroughly tamped with earth and sandbags if time and the size, shape, and location of the target permit.

112. Stringer Bridges

a. Use. The stringer bridge is the most common type of fixed bridge found in most parts of the world. It is frequently used in conjunction with other types of spans. The stringers are the load-carrying members, while the floor is dead load. Stringers may be timber, concrete, rolled steel sections, or plate girders.

b. Simple Spans. In simple span stringer bridges, the stringers extend only from one support to the next. The method of destruction for this type of superstructure is to place the charges so that they cut the stringer into unequal lengths in order to prevent reuse (fig. 79).

c. Continous Spans. Continuous spans have continous lateral supports that extend over one or more intermediate supports. Because the spans are stiffer over piers than at midspan, they may frequently remain in place even though completely cut at midspan. Steel or reinforced concrete are commonly used for such lateral supports. Continuous steel beams, girders, or trusses may be identified readily because they are either the same depth or deeper over piers than elsewhere, and there is no break or weak section over the supports. The superstructure may be demolished by cutting *each member* in *two* places *between supports* and then dropping completely the portion between the euts. Continous concrete T-beam or continuous concrete slab bridges may be recognized by the absence of construction or expansion joints over the supports.

113. Slab Bridges

The superstructure of a slab bridge consists of a flat slab supported at both ends. This is usually made of reinforced concrete, but may also be of laminated timber or a composite section of timber with a thin concrete wearing surface. If they are simple spans, the superstructure may be destroyed by the use of a single row of charges placed either across the roadway or against the bottom of the span. The breaching formula is used for reinforced concrete slabs and the timber-cutting (external charge) formula is used for laminated timber. On reinforced concrete slabs, the charges are placed twice the breaching radius apart; and on laminated timber, twice the slab thickness apart. Continuous slab spans must be cut in two plaees to insure the dropping of the slab.

114. Concrete T-Beam Bridges

a. Description. A T-beam bridge is a heavily reinforced concrete stringer bridge with the floor and stringer made in one piece. The floor acts as part of the beam. This type is heavily reinforced. T-beam bridges may be simple span, continuous span, or cantilever span.

b. Simple Span. Simple span T-beam bridges are destroyed by explosives calculated by the pressure formula or breaching formula.

c. Continuous Span. Continuous span T-beam bridges are destroyed by breaching. Charges cal-

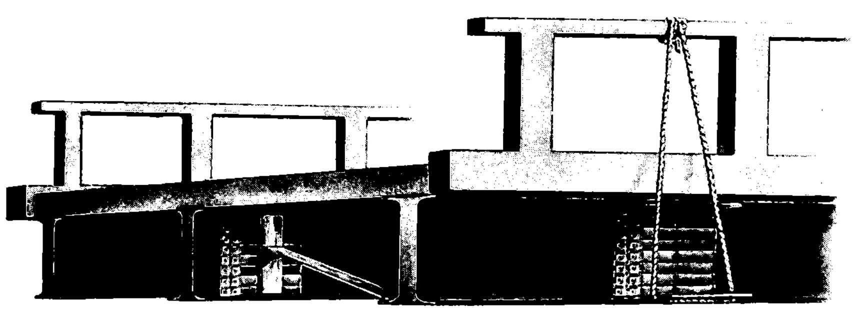


Figure 79. Placement of charges on steel stringer bridge.

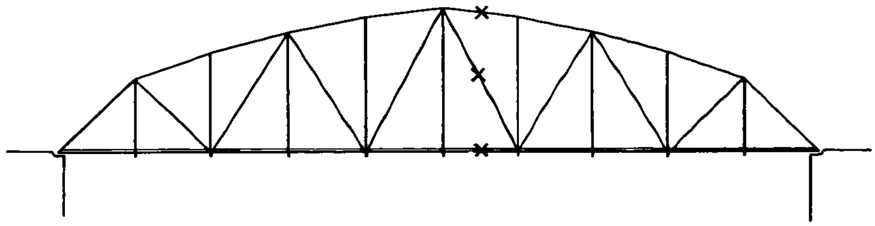


Figure 80. Placement of charges to cut upper and lower chords.

culated by the breaching formula are usually placed under the deck in order to use the thickness of the beam R. Continuous T-beam bridges may be recognized by the haunching or deepening of the section adjacent to the interior supports. Pressure charges placed at midspan on continuous concrete beams give unsatisfactory results and should not be used. It is better to demolish the piers, demolish the junction between span and pier, or remove all spans by cutting them at approximately one-quarter of their length from each end between supports. Breaching charges are used in all these cases. They may be placed on or underneath the roadway, whichever is the more convenient.

115. Truss Bridges

a. Description. A truss is a jointed frame structure consisting of straight members (steel or timber) so arranged that the truss is loaded only at the joints. Trusses may be laid below the roadway of the bridge (deck-type trusses) or partly or completely above the roadway (through-type trusses).

b. Single Span Trusses. Single span trusses extend only from pier to pier, usually having a pin joint on one end and a sliding connection at the other. Simple span trusses may be destroyed by any of the following methods:

(1) Cut the upper chord and lower chords at both ends of one truss in each span. This causes the bridge to roll over; thereby twisting the other truss off its support. Place the charges on the upper chord so that upon firing the severed upper member will not hang on the lower member and the gap will extend the width of the roadway. If the truss is too small and too light to twist free, both ends of both trusses on each span should be cut or the method described in (2) below should be used.

(2) Cut the upper and lower chords of both trusses at midspan (fig. 80). This is a more complete demolition and makes the reuse of the truss extremely difficult.

(3) Cut both trusses into segments (fig. 81).

c. Continuous Span Trusses. Continuous span trusses are usually extended over two spans, rarely over three. The heaviest chord sections and the greatest depth of truss are located over the intermediate supports. One method of demolition is shown in figure 81. In general, aside from continuity, the methods given for the destruction of simple span trusses are applicable to continuous spans. Care must be taken to make the cuts so that the bridge becomes unbalanced and collapses.

116. Concrete Cantilever Bridges

a. Description. Concrete cantilever bridges are identified by the construction joints that appear in the span but not over the piers. Figure 83 shows a cantilever bridge with a suspended span, and figure 84, a cantilever bridge without a suspended span.

b. Concrete Cantilever Bridges with Suspended Span. The superstructure of this bridge may be demolished by cutting each cantilever arm adjacent to the suspended span. If a large gap is desired, the cantilever arms should be cut in such a way as to drop the cantilever arms and the suspended spans (fig. 83).

c. Concrete Cantilever Bridges without Suspended Span. As in the bridges above, the superstructure of a cantilever bridge without suspended span is demolished by destroying the cantilever action and unbalancing the cantilever arms (fig. 84). A bridge of this type must be studied to determine the function of the members. Otherwise the charges may not be properly placed.

117. Cantilever Truss Bridges

a. Description. Cantilever truss bridges obtain their strength by having a much deeper, stronger beam section over the piers, or in effect, two "arms" that reach partially or completely across the adjacent spans. As cantilever truss bridges are a modification or refinement of continuous truss or continuous beam bridges, the demolition methods given in paragraphs 114 and 115 also apply.

b. Cantilever Truss Bridges with Suspended Span. Cantilever truss bridges with suspended span are

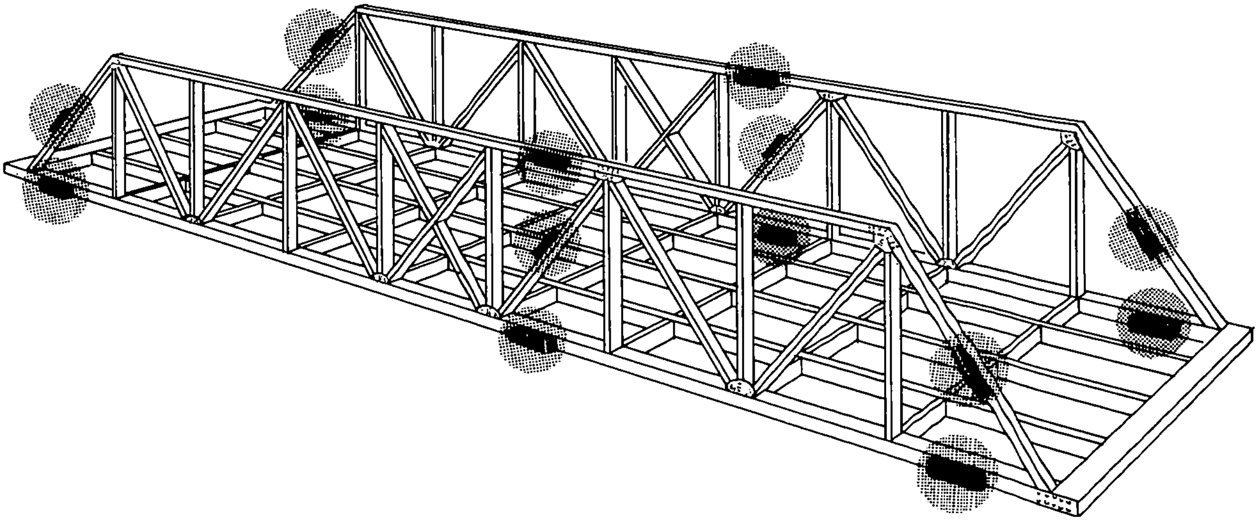


Figure 81. Placement of charges to cut trusses into segments.

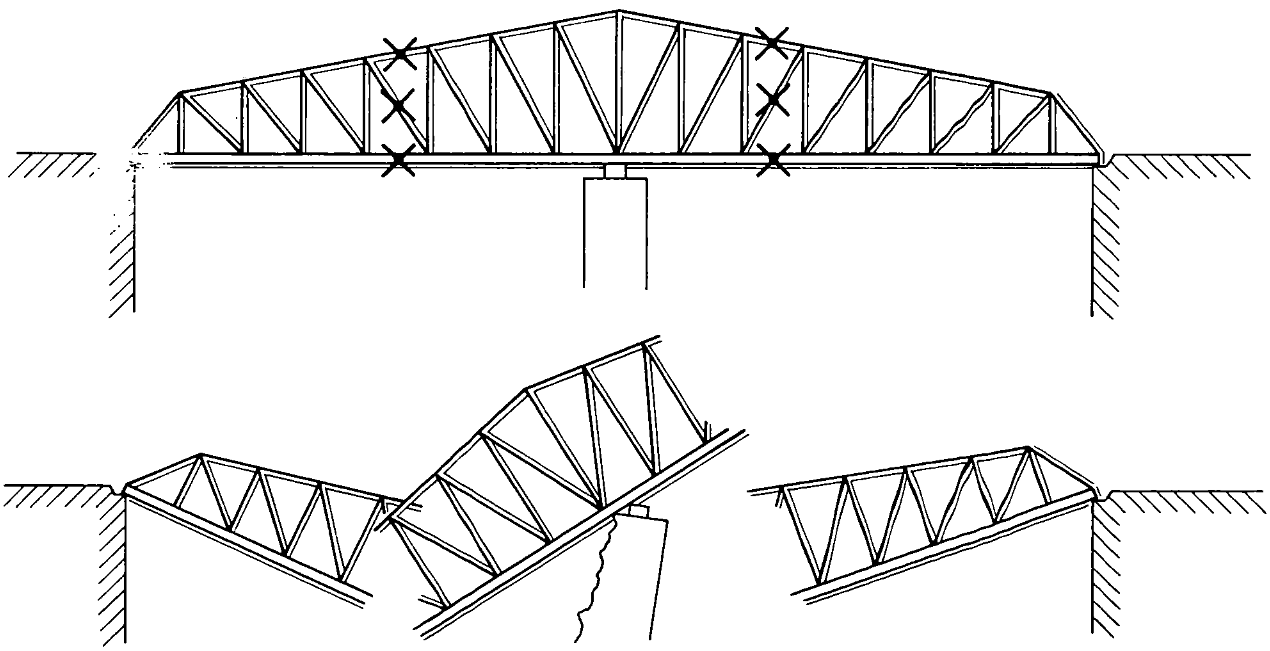


Figure 82. Placement of charges on a continuous span truss.

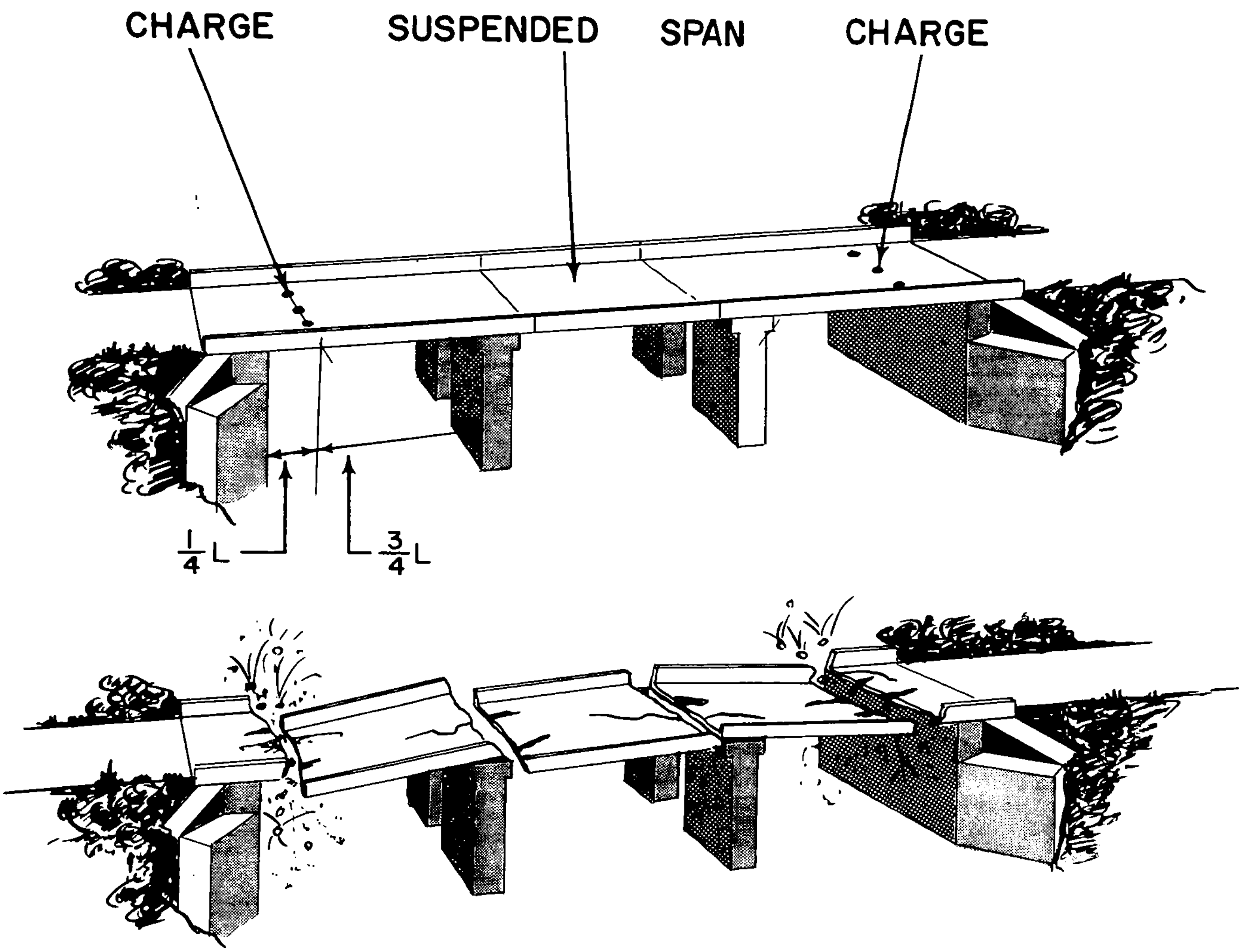


Figure 83. Demolition of concrete cantilever bridge with suspended span.

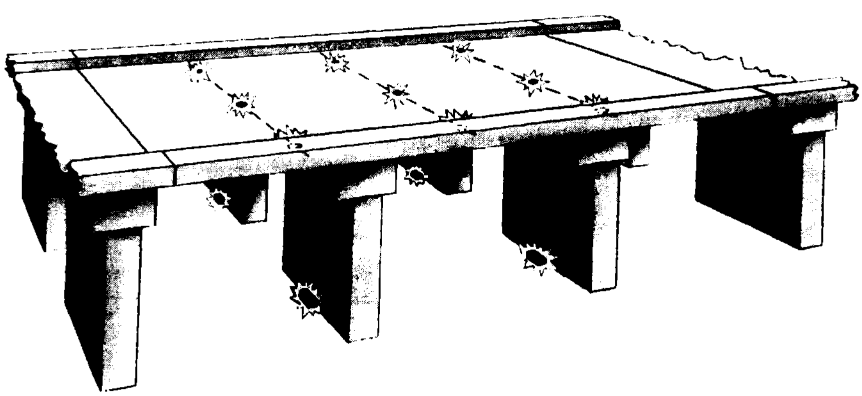


Figure 84. Demolition of concrete cantilever bridge without suspended span.

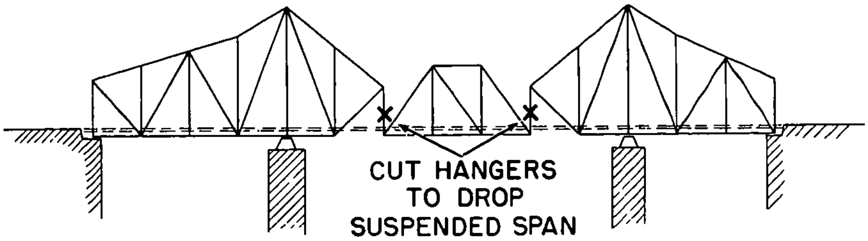


Figure 85. Demolition of cantilever truss with suspended span.

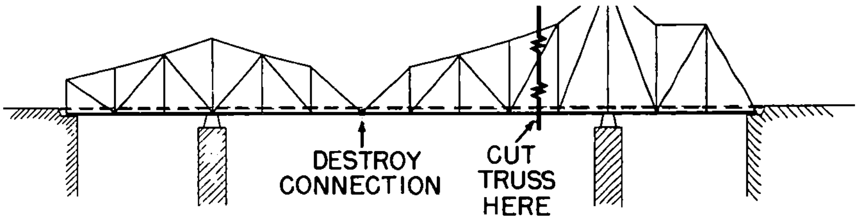


Figure 86. Demolition of cantilever truss without suspended span.

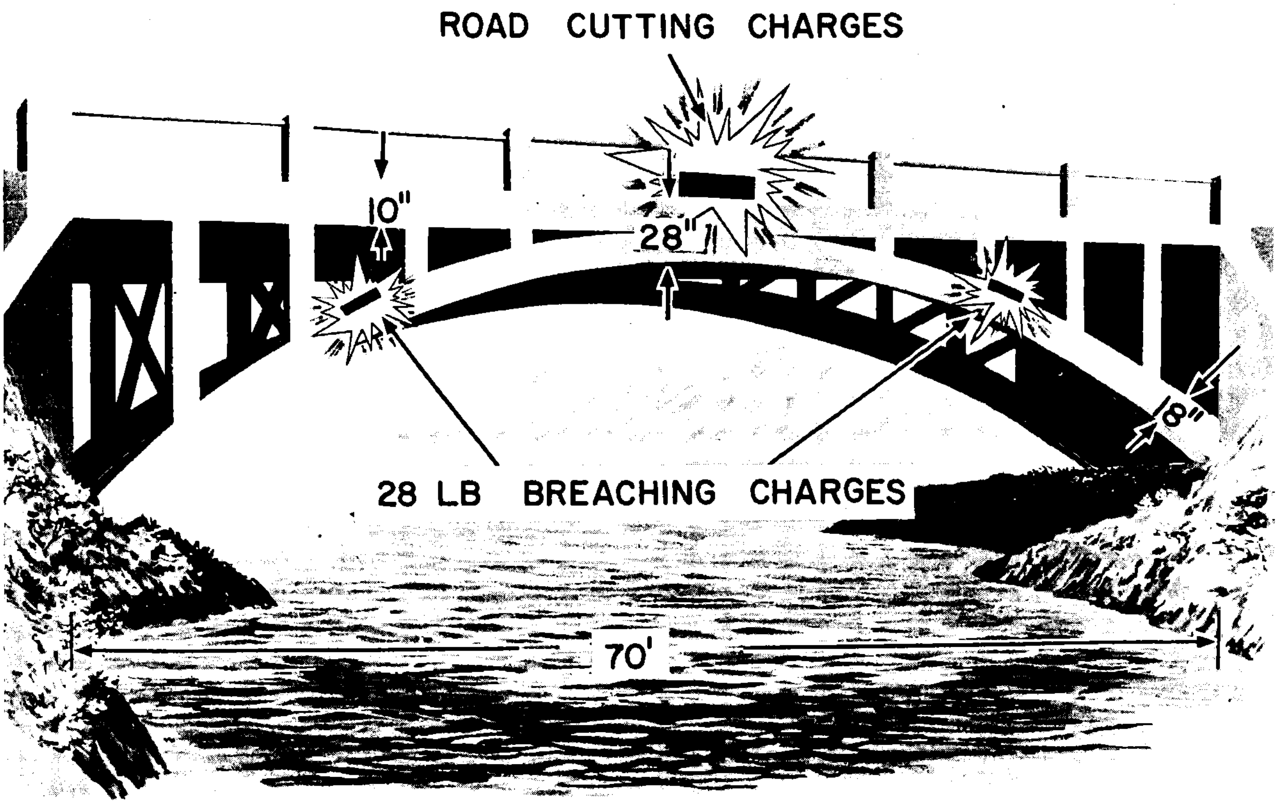


Figure 87. Demolition of a reinforced concrete open spandrel arch bridge.

invariably major bridges having suspended spans up to 700 feet long and single spans up to 1,800 feet long. They are hung from the ends of adjacent cantilever arms by means of hinges, hangers, or sliding joints. Cutting at these junctions causes these spans to drop out of the bridge (fig. 85). The cantilever arms may also be destroyed by the method described in *c* below.

c. Cantilever Truss Bridges without Suspended Span. To destroy a cantilever truss not containing a suspended span, the method shown in figure 86 is recommended. The top and bottom chords are cut at any desired point, and the bridge is cut through near the joint at the end of the arm in the same span. Another method of destruction is to cut completely through the bridge at any two points in the same span, thereby dropping out the length of bridge between the two cuts.

118. Open Spandrel Arch Bridges

An open spandrel arch consists of a pair of arch ribs that support columns or bents which in turn support the roadway. The number of arch ribs may vary, and on rare occasions the spandrel bents may be placed on a full barrel arch similar to that which supports the fill of the filled spandrel arch. The open spandrel arch bridge (fig. 87) may be constructed of reinforced concrete, steel, timber, or any combination of those materials.

a. Demolition of Concrete Open Spandrel Arch. The ribs of a concrete open spandrel arch bridge (fig. 87) are about 5 feet wide. There is usually one rib for each roadway traffic lane. The thickness of the arch rib at the crown varies from about 1 foot for spans of 50 or 60 feet in length to 3 feet for spans of 200 feet or more. The arch thickness at the spring line is ordinarily about twice the thickness at the crown. In long spans the ribs may be hollow. The floor slab is usually close to the crown, permitting easy packing of charges against the rib. Here again, the same difficulties are found in reaching the working points at the crown as in T-beam (par. 114) or in stringer bridges (par. 112). The same type of scaffolding used on other types of bridges may be used for placing demolition charges on this type. Since for structural reasons the bents over the abutments are most likely, to be heavy, effective destruction of the arch itself by means of light crown charges may leave substantial piers at roadway level in an undamaged condition. This type of structure is usually built in one massive unit rather than in lighter separate component parts and is very tough. Also, cutting the span at each end may drop the whole span a relatively short distance. This may make the damaged bridge an excellent support for building a new temporary bridge. To prevent any utilization of such a span, one charge is placed at the spring line and another at the crown. The uncut half-span will then also fall if the total span exceeds 50 or 60 feet. The charge at the spring line is computed for placement at either the rib or the pillar over the support, whichever is the greater. For short single arch spans, destroy the entire span with breaching charges laid behind the abutments or behind the haunches.

b. Demolition of Steel Arch Span. Steel arches are of four general types: continuous arches ((1), fig. 88), one-hinged arches (2), two-hinged arches (3), and three-hinged arches (4). One-hinged arches are hinged in the middle; two-hinged arches, at both ends; and three-hinged arches, at both ends and in the middle. Continuous arches and one-hinged arches are destroyed by placing charges at both ends of the span just far enough from the abutment to allow the arch to fall. Two-hinged and three-hinged arches need only one charge apiece for destruction. This should be placed at the center of the span.

119. Arch Span Bridges

a. Components. A few of the components of bridge arches are described below and illustrated in figure 89.

(1) *Span.* The horizontal distance from one support of an arch to the other.
(2) *Rise.* The vertical distance measured from the horizontal line connecting the supports to the highest point on the arch.
(3) *Crown.* The highest point on the arch.
(4) *Haunches.* Those portions of the arch that lie between the crown and the supports.
(5) *Spring lines.* The points of junction between the arch and the supports.
(6) *Abutments.* The supports of the arch.

b. Filled Spandrel Arch. A filled spandrel arch consists of a barrel arch supporting an earth or rubble fill between the retaining walls. The arch is most vulnerable at its crown, where it is the thinnest and the earth fill is usually only a foot or two thick. Filled spandrel arches are constructed of masonry (stone or brick), reinforced concrete, or a combination of these materials. They may be destroyed by either crown or haunch charges.

c. Demolition by Crown Charges. Crown charges are more easily and quickly placed than haunch charges; but their effectiveness is substantially less,

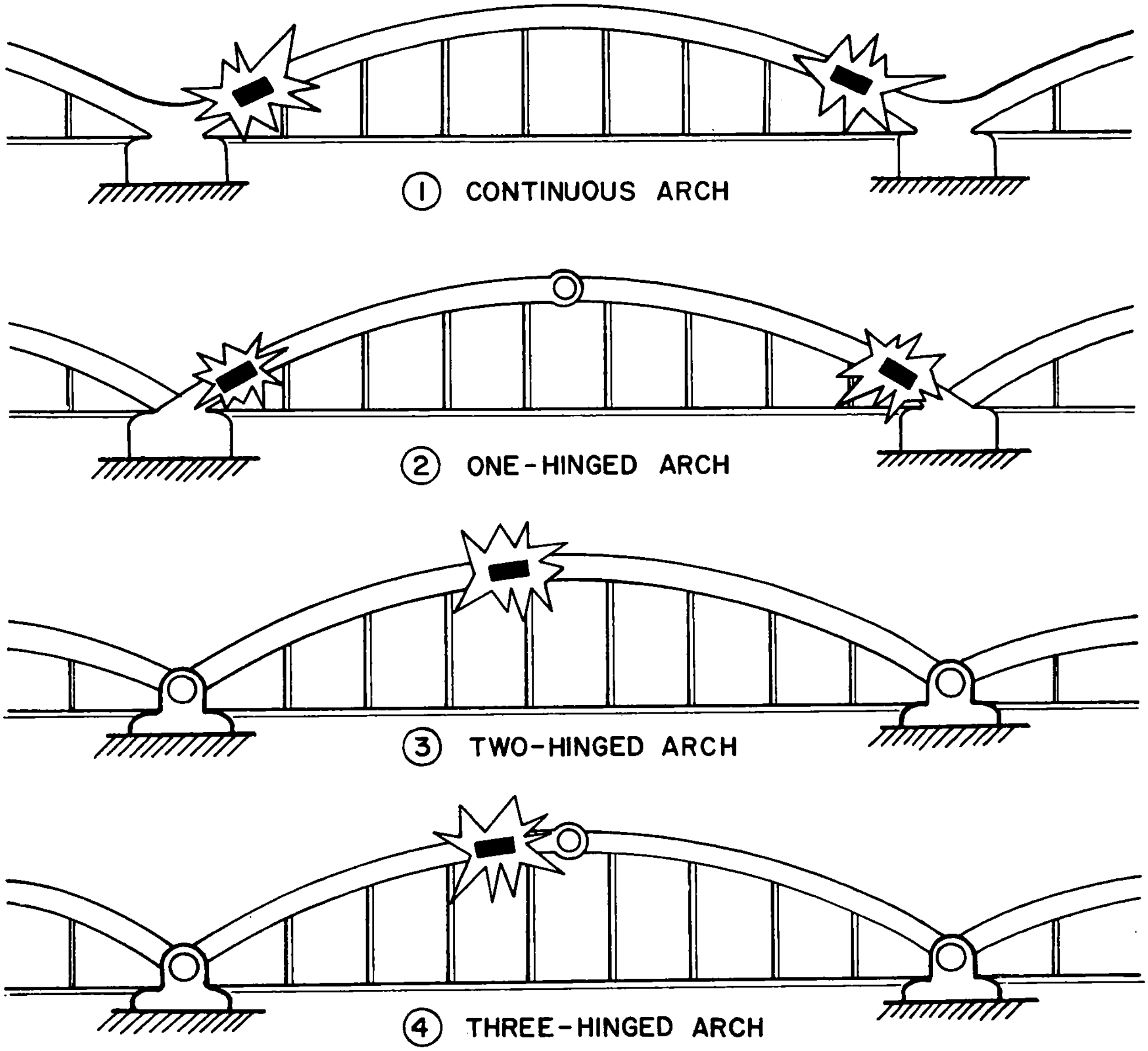


Figure 88. Placement of charges on steel arch spans.

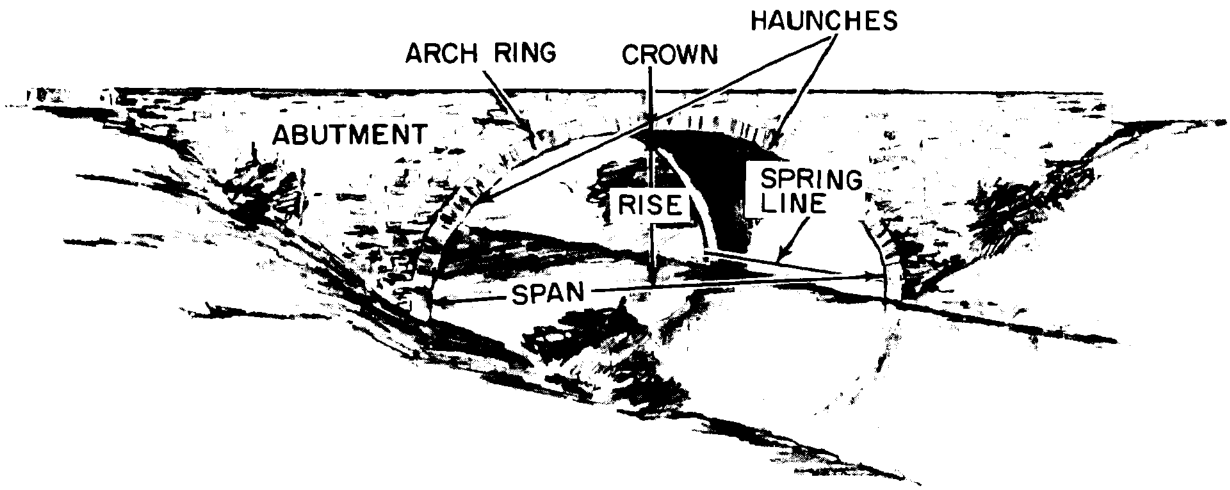


Figure 89. Arch components.

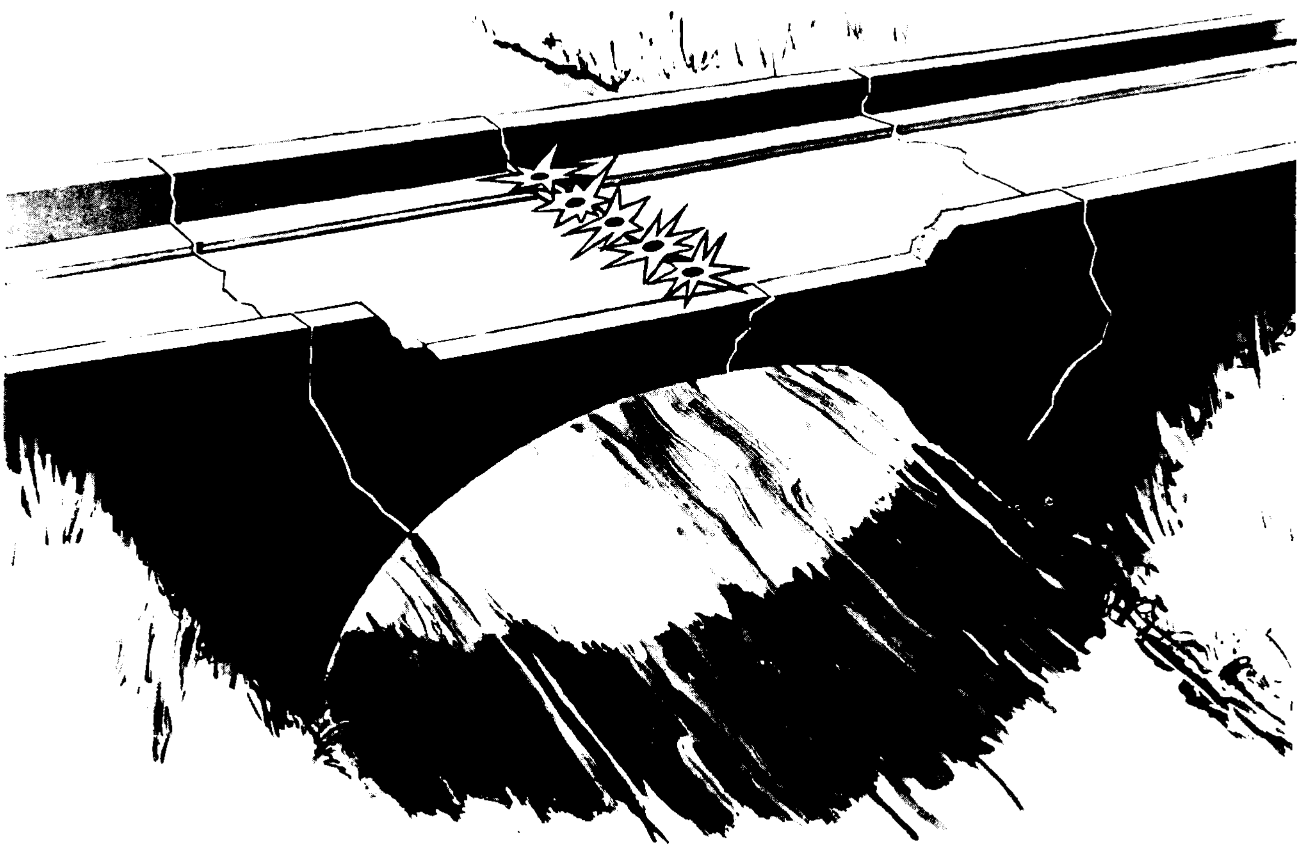


Figure 90. Breaching by crown charges on filled spandrel arch bridge.

particularly on an arch with a rise that is large in comparison with the span. Crown charges are more effective on the flatter arches because the flatter shape permits a broken portion of the arch to drop out of the bridge. The charges are calculated by means of the breaching charge formula. Charges are placed as shown in figure 90.

d. Demolition by Haunch Charges. Breaching charges may be placed at the haunches (just ahead of the abutment) and the traffic maintained until they are fired. Calculation is by the breaching formula. The placement of charges is shown in figure 91. If the bridges have vaults or chambers built into the haunches, the charges should be placed there. Their presence is usually revealed by the ventilating brick laid in the side wall of the arch. Charges placed in one haunch will drop out that portion of the arch between lines C and D in figure 90. Charges in both haunches will drop out that portion of the arch between lines C and E, figure 91.

120. Suspension Span Bridges

The suspension span bridge is distinguished by two characteristics: the roadway is carried by a flexible member, usually a wire cable, and the spans are long.

a. Components.

(1) *Cables.* Cables of suspension bridges are usually two multiple-steel-wire members that pass over the tops of towers to anchorages on each bank. The cables are the load-carrying members.

(2) *Towers.* Towers of a suspension bridge support the cables or load-carrying members. They may be made of steel, concrete, or masonry.

(3) *Trusses or girders.* The trusses or girders of a suspension bridge do not support the load directly. They provide stiffening only.

(4) *Anchorage.* The usual anchorage is merely the setting of the ends of the cable in a rock or concrete mass.

b. Destruction.

(1) *Major structures.* The towers and anchorages of a major suspension bridge are usually too massive to be destroyed, and the

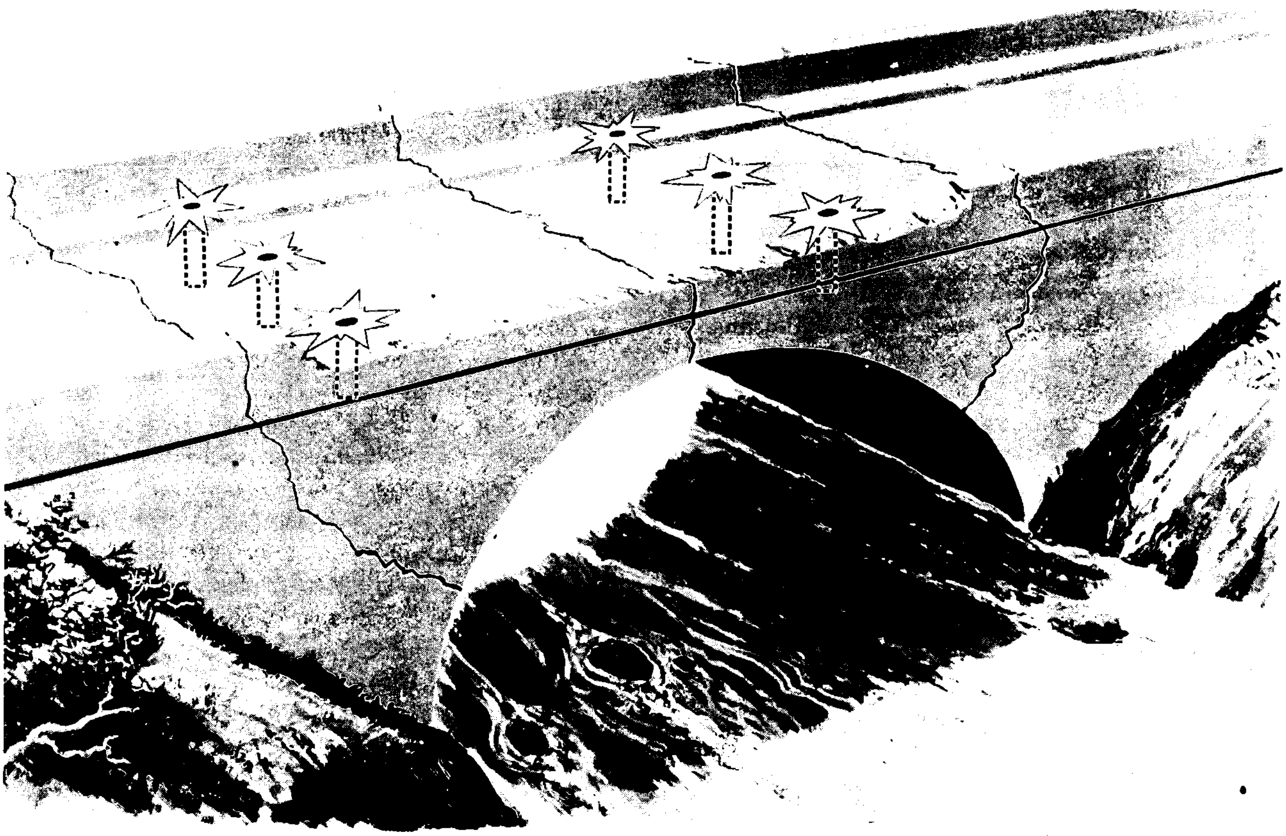


Figure 91. Breaching by haunch charges on filled spandrel arch bridge.

cables are too thick for positive cutting with explosives. The most economical method of destruction is either by dropping the span leading onto the bridge or by dropping a section of the roadway. The length of this section should be determined by an analysis of what capabilities the enemy has for repair in the time he is expected to retain the site, particularly the erection of a prefabricated bridge.

(2) *Minor structures.* The two vulnerable points of a minor suspension bridge are the towers and the cables.

(3) *Towers.* Charges may be placed on the towers slightly above the level of the roadway. A section should be cut out of each part on each tower. A charge is placed on each post to force the ends of the cutout section to move in opposite directions. This will prevent the ends of a single cut from remaining in contact.

(4) *Cables.* Charges should be placed on the cables as close as possible to an anchorage. Extreme care should be taken to extend the charges not more than one-half the distance around the circumference of the cable. These charges are bulky, exposed, and difficult to place; and the cables are difficult to cut. Shaped charges, however, with their directed force effect, may be used to advantage in cutting a cable.

121. Floating Bridges

Floating bridges consist of a continuous roadway of metal or wood supported by floats or pontons.

a. Pneumatic Floats. Pneumatic floats consist of rubberized fabric made into airtight compartments and inflated with air.

(1) *Hasty method of destruction.* The anchor cables and bridle lines may be cut with axes and the steel cables, by explosives.

(2) *Deliberate method of destruction.* The floats may be punctured by small arms or machinegun fire. This requires a considerable volume of fire because of the large number of watertight compartments in each float. Detonating cord stretched snugly across the surface of inflated ponton compartments will make a clean cut through the material. One strand will suffice to cut most fabrics; two may be required for heavier material. Also one turn of detonating cord around an inflation valve cuts it off at the neck or does other damage. Lines placed around valves should not be main lines but branch lines run off from the main line, as the blast wave may fail to continue past the sharp turn.

b. Rigid Pontons. Rigid pontons are made of various materials such as wood, plastic, or metal. Most of these are open but occasionally they are decked over.

(1) *Hasty method of destruction.* If the current is rapid, the anchor cables may be cut so that the bridge will wash downstream. A ½-pound charge of explosive should be placed on the upstream end of the bottom of each boat and next to the column of each trestle and detonated simultaneously.

(2) *Deliberate method of destruction.* The bridge is severed into rafts and half-pound charges of explosives are placed at each end of each ponton and detonated simultaneously.

c. Treadways. Charges to destroy the treadway of any metal treadway type of floating bridge may be calculated by means of the steel-cutting formula. The placement and amount of the charges to be used depends on the type of bridge to be destroyed. In general, if charges are set to sever the roadway completely at every other joint in the treadway, the bridge will be damaged beyond use.

122. Bailey Bridges

A basic 1-pound charge placed between main members will cut the upper and lower chords. A ½-pound charge will cut the diagonals and a 1-pound charge, the sway bracing.

a. Bridge in Place.

(1) The bridge is severed into parts by cutting panels on each side, including the sway braces. The line of cut is staggered through the panels; otherwise the top chords may jam and prevent the bridge from dropping. In double-story or triple-story bridges, the charges are increased on the chords at the story junction line.

(2) For further destruction, charges are placed on the transoms and the stringers.

b. Bridges in Storage or Stockpile. Destruction of bridges in storage must be such that the enemy cannot use any of them as a unit or any parts for normal or improvised construction. This requires that one essential component, not easily replaced or improvised, be destroyed, so that not only the bridges at a particular stockpile will be damaged, but others throughout the theater. In this way it will be impossible for the enemy to obtain replacements from other sectors. The component that fulfills all of these conditions is the panel. To make the panel useless, the female lug in the lower tension cord is removed or distorted. All panels should be destroyed before other components are destroyed.

Section IV. DISRUPTION OF TRANSPORTATION LINES

123. Highways

Disruption of enemy lines of transportation is one of the most important objectives of demolition work. By the destruction of the road net, the attacking forces are halted or delayed, the movement of supplies is prevented, and frequently new construction is required before the enemy can advance. This may be accomplished by the demolition of bridges, by blowing road craters, by placing wrecked items of equipment and debris in cuts and defiles, and by the construction of abatis and roadblocks. Planning factors for highway denial are found in table XI.

124. Railroads

a. Tracks.

(1) The destruction of railroads with explosive should be done at vulnerable points. These are curves, switches, frogs, and crossovers, which may be easily destroyed with a small amount of explosive. Placement of charges is shown in figure 92. A length of single track may be destroyed rapidly by a detail of soldiers with a push car, ¼-ton truck, or other vehicle supplied with explosives, blasting caps, fuzes, fuse lighters, and sandbags. Several soldiers ride the vehicle, prepare 1-pound primed charges, and hand them, together with sandbags, to men walking immediately behind the vehicle. These men place the charges against the rails on alternate connections of both tracks for a distance of about 500 feet, and then tamp them well with sandbags. Tamping is not required to break the rail, but will destroy a longer length of rail. Other soldiers follow about 250 yards behind the vehicle to light the fuzes. This demolition should be repeated at about 1½-mile intervals. If because of shortage of explosives or time or because of other factors, it is not possible to completely destroy all of the track, the method just described is excellent; for it causes more delay in repairing the track than the concentration of all destruction along one

Table XI. Planning Factors for Highway and Railroad Denial

Type target	Material				Manpower	
	C–4 lb	TNT lb	Thermite grenades	Cratering charges (40 lb cases)	Man hrs	Squad hrs
Highways:						
Tunnels		12,000			50	5
Major bridges (over 400 ft)		1,200			30	3
Minor bridges (under 400 ft)		800			20	2
Road defiles		500		102	120	12
Railroads:		12,000			50	5
Major bridges (over 400 ft).						
Single track		3,000			60	6
Double track		4,500			60	6
Minor bridges (100 to 400 ft).						
Single track		2,000			40	4
Double track		3,000			40	4
Terminal facilities	542	30	43		32	3.2
Rolling stock (locomotive and 30 cars)	6		121		31.5	3.2

Note. Squad hours are based on average 10-man squad. Material quantities are those required for destruction of a single target of type listed. Total material requirements for rendering a system inoperative depend upon the total number and types of targets destroyed.

stretch of track. Destruction of *all* of the track, however, causes more delay than this method of "spot" destruction. The destruction of every other connection between rails on both tracks increases the problem of repair. A stretch of 500 feet of single track railroad requires about 20 pounds of explosive for the "spot" destruction described above.

Note. Safety precautions must be taken during this operation. Ample time must be given the persons lighting the fuses to reach a safe distance before the charges are detonated.

(2) *Other destruction methods.* Tracks may be made unserviceable without the use of explosives by overturning sections on embankments or fills—removing fishplates from both ends of a section of track, fastening a heavy chain to the section, and pulling it up with a locomotive—or by tearing up the ties and rails with a large hook pulled by a locomotive. Ties loosened from the rails may be piled and burned. Planning factors for railroad denial are found in table XI.

b. Roadbeds. Roadbeds are damaged by the same methods used in making road craters and antitank ditches.

125. Tunnels

Railway and highway tunnels, located on major routes to strategic industrial or military areas, are vulnerable to demolition and therefore desirable targets. Tunnel demolition, however, with hastily placed conventional explosives is impossible unless huge quantities are used. But when demolition chambers exist and time, men, and equipment are available, considerable damage to tunnels can be accomplished with reasonable amounts of explosive. Planning factors for tunnel denial are found in table XI.

a. Principal Factors in Tunnel Demolitions. The most critical factor in tunnel demolition is the tightness of the lining against solid rock. The actual thickness and strength of the lining are of secondary importance. The degree of contact of the walls with the surrounding rock influences the amount of blast energy transmitted to the rock or retained in the concrete and the consequent movement of broken fragments, which may permit their being dislodged and dropped into the tunnel.

b. Hasty Demolitions. The hasty demolition of tunnels with reasonable amounts of conventional high explosives is ineffective. No hasty method has yet been devised that will cause extensive damage. The enemy may be temporarily deprived of the use of a tunnel by breaking and dislodging portions of the lining with normal breaching charges placed at a number of points and by creating slides at the tunnel portals by placing cratering charges in the slope above them. Nuclear devices of proper size advantageously placed, will demolish a tunnel.

c. Deliberate Demolitions. Deliberate tunnel demolitions will produce satisfactory results when ex-

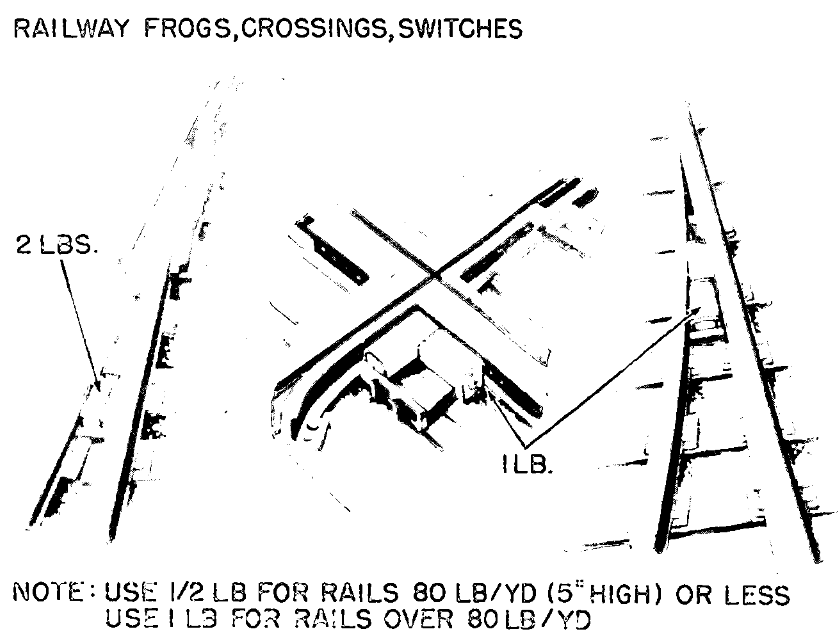


Figure 92. Demolition of railroad switches, frogs, and crossovers.

plosive charges are detonated in prepared chambers in the material adjacent to the inner face of the tunnel, whether it is lined or not. Excessive charges are not required. Maximum damage desired in any tunnel is that of obstructing it with broken rock. Secondary damage by fire may also occur. Caving, which may result from structural damage to the tunnel arch, cannot be predicted. To obtain maximum damage to tunnels, the methods outlined below are adequate.

(1) *Charge chambers.* Tunnel charge chambers should be so constructed that each chamber parallels the long axis of the tunnel at or above the spring line. The **T**-design tunnel charge chamber in an efficient means of inflicting serious damage. The chambers may be constructed opposite each other, at staggered intervals on opposite sides, or all on one side of the tunnel. The maximum burden, which is the distance from the charge to the inside rock wall, should be 15 feet. The tunnel charge chamber should be no larger than necessary for convenience of construction and loading and no smaller than 3 feet wide by 4½ feet high. Charge chambers should be constructed far enough inside the tunnel portal to insure confinement of the charge. The minimum of side hill or outside burden should be 30 feet.

(2) *Charges.* Seven hundred and fifty pounds of high explosive is an effective minimum charge for single placement within a **T**-type chamber of 15-foot burden. Charges should be placed on 30-foot centers.

(3) *Stemming.* Stemming, the material with which a borehole or charge chamber is filled or tamped (usually earth filled sandbags), is necessary. It should extend from the last charge in the **T**-type chamber to the chamber entrance. Stemming is not necessary between charges within the chamber. The length of the stemming column should exceed the length of burden.

d. Deliberate Demolition of Tunnels With Prepared Charge Chambers. Some tunnels have chambers or holes in the roof for the purpose of demolishing them at some future time. Their presence is usually indicated by the open brick ventilators placed over them. If no ventilators are present, these chambers may be located by striking the roof of the tunnel with some heavy metallic object, which usually produces a hollow sound. Explosives, compacted as tightly as possible, are placed in the chambers, which are then closed and sealed except for the place where the fuze or firing wire passes through. Sandbag stemming is recommended in all charge chambers in timbered tunnels, as the sandbags increase the possibility that the timbers may ignite when the charge is detonated.

126. Water Transportation Systems

a. Vessels, Piers, and Warehouses. Water-born vessels can seldom be destroyed efficiently by land-based troops, unless they are tied up at docks or piers. Docks, piers, and warehouses, however, are excellent demolition objectives.

b. Channels. The most expeditious way to block a channel is to sink a ship or a loaded barge at a point that cannot be bypassed. Channels with retaining walls may be blocked effectively by detonating breaching charges behind the retaining walls.

c. Dams. Since a prohibitive amount of explosive is generally required to destroy an entire dam structure, the best and quickest method is to destroy the machinery and the equipment. If the purpose of the demolition is to release the water in the reservoir, all that is required is to destroy the gates on the crest of the dam, the penstocks or tunnels used to bypass the dam or to carry water to hydroelectric plants, or the valves or gates used to control the flow in those penstocks or tunnels. In dams with breasts partly or wholly constructed of earth fill, it may be possible to ditch or crater down below the existing waterline and thus allow the water itself to further erode and destroy the dam.

d. Canals. In most cases a canal may be made useless by destroying the lock gates and the operating mechanism that controls them. This mechanism, which includes the electrical equipment and perhaps pumps, is the easier to destroy and should, therefore, be attached first. If time permits, the gates themselves may be destroyed. The lock walls and canal walls may be destroyed by breaching charges or cratering charges placed behind them. Planning factors for waterways denial are found in table XII.

127. Airfields

Airfields may be destroyed by ADM or rendered unusable by cratering runways, placing objects on surfaces to prevent use by aircraft, and the destruction of POL and munitions stocks and repair and communications facilities. Rooters, plows, and bulldozers can ditch runways that are not constructed of concrete. Friendly operational and non-

Table XII. Planning Factors for Waterways Denial

Type target	Material			Manpower	
	C-4 (lb)	TNT (lb)	Cratering charges (40-lb cases)	Man hrs	Squad hrs
Waterway facilities:					
Locks	110			6	.6
Inland port facilities	20	20		4	.4
Weir		1,000		20	2.0
Aqueduct, siphon, or levee wall			15	20	2.0
Dam (navigational)	500			25	2.5

Note. Squad hours are based on 10-man squad. Material quantities are those required for destruction of a single target of type listed. Total material requirements for rendering a system inoperative depend upon the total number and types of targets destroyed.

Table XIII. Planning Factors for Airfield Denial

Type target	Material			Manpower	
	TNT (lb)	M-3 shaped charges	Thermite grenades	Man hrs	Squad hrs
Runways, per 1,000 ft	5,500	25		80	8.0
Facilities:					
Fuel storage, per tank 400	400		1	10	1.0
Radar and radio apparatus	30		10	4	0.4

Note. Squad hours are based on average 10-man squad. Material and manpower requirements are based on destruction of essential target elements only.

operational airfields, made ready for demolition only during the preparation for an organized withdrawal when seizure by the enemy is imminent, should be destroyed only in areas where the resulting wreckage will provide the maximum impediment to enemy movement and operations. Planning factors for airfield denial are found in table XIII.

a. Plans for Demolition.

(1) The methods of destroying any airfield depend on the materials at hand, the type of installation to be destroyed, and the time available to complete the job. Aircraft and equipment may be destroyed instantly by directing weapons fire against them. Whenever possible, bombs and ammunition should be used as explosive charges (app. III). Gasoline may be used to aid in the destruction by fire of vehicles, equipment, and buildings.

(2) When time permits, a detailed plan for demolition of the airfield should be prepared before any charges are placed. This should include—

(*a*) Location of charges.

(*b*) Type of explosives.

(*c*) Size of each charge.

(*d*) Priority in preparation of each charge.

(*e*) Total amount of itemized explosives and other materials needed to effect demolitions included in the plan.

(*f*) Assignment of personnel or groups to prepare specific charges.

b. Priorities for Demolition. It is seldom possible to destroy an airfield completely because of the great amount of explosives and time required. Thus it is necessary to determine what specific demolition is to be done and in what order specific operations are to be accomplished. Airfield demolition plans should be very flexible, particularly in regard to priorities. The order of priority should vary according to the tactical situation. The following list suggests an order of priority for airfield demolition, which may be modified to suit the tactical situation.

(1) Runways and taxiways and other landing areas.

(2) Routes of communication.

(3) Construction equipment.

(4) Technical buildings.

(5) Supplies of gasoline; oil, and bombs.

(6) Motor vehicles and unserviceable aircraft.

(7) Housing facilities.

c. Runways and Taxiways. Runways and taxiways have first priority in a demolition plan because the destruction of landing surfaces is the most important single item. Whenever possible, demolition of an airfield should be considered during construction by the placing of large conduits in all fills. This requires little extra work and provides a means of placing explosives under the runway. Standard deliberate and hasty craters may be useful in the demolition of runways and taxiways. Shaped charges may be used to breach thick concrete pavement when speed is essential. The placing of individual cratering charges diagonally down the runways or taxiways, or in a zigzag line running diagonally back and forth, results in more complete destruction. When pierced steel plank or other type of landing mat is used on an airfield, substantial damage may be done by attaching a large hook to sections of the mat and pulling it out of place with a tractor. This should be followed by cratering. A hasty, satisfactory obstacle may be produced by the use of 40-pound cans of cratering explosive, spaced every 15 feet across the runway and buried 4 feet under the ground.

d. Turf Surfaces and Pavements. Turf surfaces, bituminous surface treatments, or thin concrete pavements may be destroyed by bulldozers, graders, and rooters. Turf airstrips may also be destroyed by plowing or cratering.

e. Aircraft. Unserviceable aircraft should be destroyed by the detonation of 4 pounds of TNT placed on each crankshaft between the propeller and the engine and 1 pound of TNT placed on the instrument panel. The engines of jet-propelled aircraft should be destroyed by detonating charges on essential parts, such as the compressor or the exhaust turbine. Radio equipment, bombsights, radar, and tires should be removed or destroyed. Thermite grenades are also useful in airplane destruction.

128. Pipelines

The most vulnerable points of a pipeline system are the storage tanks and pumping stations. Planing factors for POL facilities denial are found in table XIV.

a. Storage Tanks. Storage tanks filled with fuel may be destroyed most effectively by burning with incendiary grenades or the burst of .50-caliber incendiary ammunition. If the tank is filled with water or other noncombustible material, it may be burst by detonating charges internally against the sides of the tank near the bottom. Empty tanks may be destroyed by detonating charges against the base.

b. Pumping Stations. Booster pumping stations on cross-country pipelines, being very vulnerable, should be destroyed. Gravel or other solid objects introduced into the pipeline while the pumps are running will damage the moving parts, although not to the degree possible with explosives. If time permits, the pumping station should be burned after the equipment has been destroyed by explosives.

c. Pipe. The pipe used in pipelines is destroyed only during scorched earth operations because of the great amount of effort necessary to effective damage. Junctions, valves, and bends are the most suitable points, particularly when the line is buried. Another method is to close all valves on the line; the expansion that occurs, even in subzero weather, will break it.

Table XIV. Planning Factors for POL Facilities Denial

Type target	Material			Manpower	
	C-4 (lb)	Cratering charges (40-lb cases)	Thermite grenades	Man hrs	Squad hrs
Storage and handling facilities	4	15	10	11.5	1.2
Refining facilities	80	------------	15	7.5	0.8
Producing and distributing facilities	10	------------	2	1.5	0.2

Note. Squad hours are based on average 10-man squad. Material quantities are those required for destruction of a single target of type listed. Total material requirements for rendering a system inoperative depend upon the total number and types of targets destroyed.

Section V. DISRUPTION OF COMMUNICATIONS SYSTEMS

129. Telephone and Telegraph Lines

Although damage to an enemy telephone system or telegraph system may never be extensive, it does have a great delaying effect. Telephone and telegraph switchboards and instruments are the best points of attack. Generally 1-pound charges placed on the lead cables are adequate to sever them. Pole lines are not satisfactory targets as they are strung over long distances and can be destroyed only in spots. They may be made temporarily useless by cutting or grounding the wires. Pole lines are completely destroyed by cutting the poles with small external timber-cutting charges and then burning. The wire should be cut into short lengths to prevent further use. Planning factors for telecommunications denial are found in table XV.

130. Radio Installations

Radio provides rapid communication between far distant points that would otherwise be without communication. Antenna towers, usually constructed of steel and braced with gun wires, are the weakest part of any radio installation. They are destroyed by cutting the guy wires and by placing cutting charges against the base. The towers should be toppled over the transmitter station or across the high voltage transmission line through which the installation receives its power. Equipment and standby power units may be destroyed by mechanical means or by demolition charges.

Table XV. Planning Factors for Telecommunications Denial

Type target	Material		Manpower	
	C-4 (lb)	Thermite grenades	Man hrs	Squad hrs
Telegraph exchanges	10	1	1	0.1
Telephone exchanges				
Telephone, automatic	20	2	2	0.2
Telephone, manual	10	2	2	0.2
Repeater stations	40	---------	2	0.2
Radio station	40	---------	2	0.2
Radio link terminal	40	---------	2	0.2

Note. Squad hours are based on average 10-man squad. Material and manpower factors are adequate to render the average telecommunications facility inoperative, but only for a time, dependent on available equipment, personnel, and rehabilitation needs. The system is effectively disrupted if the enemy cannot use it to supplement his requirements in the area. Material quantities are those required for destruction of a single target of type listed. Total material requirements for rendering a system inoperative depend upon the total number and types of targets destroyed.

Section VI. DESTRUCTION OF BUILDINGS AND INSTALLATIONS

131. Buildings

Buildings may be destroyed by explosives or other methods. The methods used and the extent of demolition usually depend on the time available.

a. Masonry or Concrete Buildings. Masonry or concrete buildings may be destroyed by breaching charges placed on the inside and on the base of the exterior walls.

b. Wood or Thin Walled Buildings. Wooden frame buildings may readily be destroyed by fire. Another method is to close all doors and windows and explode on the ground floor a concentrated charge equal to ¼ pound to 1 pound of explosive per cubic yard of volume. Such buildings may be dismantled, however, if time permits.

c. Steel Frame and Buildings. Buildings with steel frames may be destroyed by first breaching the concrete or masonry to expose the vital steel members and then cutting them with explosive charges.

d. Concrete Beam, Curtain Wall Buildings. Concrete beam curtain wall buildings and industrial installations, constructed in such a way that the load is carried by reinforced concrete beams and columns, are destroyed by placing breaching charges inside the building at the base of the exterior wall and at the base of all intermediate columns on the ground floor.

132. Electric Power Plants

Electric power plants are destroyed by cutting the windings of generators and motors or by placing and detonating a 2-pound charge inside the casings. The shafts of motors and generators are broken. All metering equipment is torn out and destroyed. All transformers are demolished. Damage can also be done by removing or contaminating the lubricating oil and then running the machinery. Boilers are burst with a cutting charge. All buildings, transmission towers, penstocks, and turbines of hydroelectric plants are destroyed.

133. Water Supply Installations

The pumping station and reservoirs of a water supply system are usually the points most vulnerable to attack. The machinery is destroyed or made unserviceable. Some reservoirs may be destroyed by breaching charges placed in the side walls. Water tanks are demolished by charges calculated on the basis of 1 pound of explosive per 100 cubic-foot capacity. The charge is detonated inside the tank when it is full of water. The water acts as a tamping material. Wells sunk in soft soils are damaged beyond repair by charges that cut the lining. Wells in rock and hard soils, having little or no lining, are demolished by exploding large breaching charges 6 to 12 feet from the edge of the well and deep enough to secure good tamping. If time does not permit such preparation, a large charge is exploded halfway down against the side. When possible, the rising main and pump rods are disconnected and dropped to the bottom.

134. Petroleum, Oil, and Lubricant Refineries

POL refineries are readily demolished. Cracking towers, steam plants, and pumps are destroyed by explosives; and cooling towers and POL stock, by fire.

Section VII. DESTRUCTION OF EQUIPMENT AND SUPPLIES

135. Introduction

a. Authority for Destruction. The destruction of materials is a command decision, implemented only on authority delegated by the division or higher commander. Equipment and supplies that cannot be evacuated and may, therefore, be captured by the enemy are destroyed or made unserviceable, except for medical materials and stores, which are not to be intentionally destroyed (DA Pam 27–1 and FM 8–10).

b. Destruction Areas. Whenever possible, mobile equipment is demolished in places where it most effectively impedes the advance of the enemy. Examples of such places are—

(1) Approaches to bridges (fills).
(2) Airfield landing strips.
(3) Cuts, fills, or hills on roads.
(4) Sharp bends of roads.
(5) Roads leading through densely wooded areas.
(6) Narrow streets in thickly populated or built-up areas.

c. Priority of Operations. Destruction must be as complete as the available time, equipment, and personnel will permit. If all parts of the equipment cannot be completely destroyed, the most important ones should be damaged. Special attention must be given to those parts that are not easy to duplicate or rebuild. Particular care must be taken that the same components are destroyed on each piece of equipment; otherwise the enemy may assemble a complete unit with parts taken from several partly destroyed units (cannibalization).

d. Precautions. When material is destroyed by explosives or by weapons fire, flying fragments and ricocheting bullets create a hazard. Thus demolition must be accomplished in an area free of friendly troop concentrations.

136. Plans for Destruction of Equipment

Standing operating procedures for all units should contain a plan for the destruction of equipment and supplies not including medical supplies, which are left intact. Such a plan will insure that the maximum and most effective damage is done to materiel and will deny the use of friendly equipment to the enemy. It should outline the required extent of demolition and include priorities of demolition and methods of destruction for all items issued to the unit. If explosives are to be used, the amounts required should be indicated. The plan must be flexible enough in its designation of time, equipment, and personnel to meet any situation. In order to make cannibalization by the enemy impossible, each equipment operator must be familiar with the priority sequence in which essential parts, including extra repair parts, are to be destroyed. He must also be familiar with the sequence to be followed for total destruction.

137. Methods of Destroying Materiel

The following methods of destroying materiel may be used either singly or in combination. The actual method or methods used in a given situation depend on the time, personnel, and means available.

a. Explosives. As all military explosives are effective in destroying equipment, their use is one of the two preferred demolition methods.

b. Mechanical Means. The other of the two preferred methods for destroying materiel is mechanical means. Sledge hammers, crowbars, picks, axes, and any other available heavy tools are used to smash or damage whatever is to be destroyed.

c. Weapons Fire. Hand grenades, rifle grenades, antitank rockets, machinegun fire, and rifle fire are a valuable means of destroying materiel. The heaviest available weapon should be used.

d. Thermite Grenades. Flammable material and equipment may be destroyed or made unserviceable by heat generated by the thermite grenade. The material should be soaked with fuel before burning.

e. Fire. Rags, clothing, or canvas should be packed under and around the materiel to be destroyed. It should then be soaked with gasoline, oil, or diesel fuel. Damage from fire may not always be as severe as expected. Engine or transmission parts heated to less than a dull red heat are not seriously damaged provided they are lubricated immediately after the fire to prevent corrosion. Electrical equipment, including motor or generator armature windings and other wiring, is effectively destroyed by burning. All parts made from low-melting-point metal may be almost completely destroyed by fire.

f. Water. The damage resulting from submerging equipment in water is not generally very severe, but the method is sometimes rather quickly and easily accomplished. Total submersion also provides concealment of equipment (*h* below).

g. Abuse. Much damage can be done to equipment, particularly to engines, by deliberate improper operation. Such abusive treatment may proceed even after abandonment, if hasty action becomes necessary, by leaving the equipment in an improper operating condition.

h. Concealment. Easily accessible vital component parts of equipment may be removed and scattered through dense foilage, thus preventing, or at least delaying, use by the enemy, Vital parts of entire items may be hidden by throwing them into a lake, stream, or other body of water (*f* above).

i. Boobytrapping. Boobytraps are placed in the debris after destruction is completed, if there is time. See FM 5–31 for the techniques.

138. Destruction of Combat Equipment

There are various publications on the proper methods of destroying military combat equipment. The FM 23-series is concerned with the destruction of small arms such as rifles, pistols, mortars, and ammunition; and the FM 17-series, with the destruction of armored vehicles and their weapons.

139. Training

Training does not involve the actual demolition of any materiel but the simulated breaking of vital parts, the placing of dummy charges, and the selection of sites suitable for the destruction of equipment in order to block communication routes. Drivers and operators should be made familiar with each step in the appropriate method for the destruction of equipment and supplies. The correct sequence of operations should be emphasized as follows:

a. Mechanical damage to vital parts.

b. Explosives.

c. Weapons fire, fire, and water.

CHAPTER 5
SAFE HANDLING, TRANSPORTATION, AND STORAGE OF EXPLOSIVES

Section I. GENERAL SAFETY PRECAUTIONS

140. Safety Rules and Responsibility

a. Compliance. Safety rules regarding explosives, caps, and demolition equipment will be followed strictly during training. In all other situations they will be observed to the fullest extent permitted by time, materials available, and requirements of the mission. Also, post regulations and local and unit SOP's will be observed.

b. Responsibility. The responsibility for the preparation, placement, or firing of charges must not be divided. One individual should be responsible for the supervision of all phases of the demolition mission.

141. Safe Distance Formula

Distances at which persons in the open are safe from missile hazards from bare charges placed in or on the ground are given in table XVI. The formula for computing safe distances from explosives so placed is: Safe distance in feet $= 300 \sqrt[3]{\text{pounds of explosives}}$. The minimum safe distance for soldiers in a missile-proof shelter is 300 feet.

142. Package Care and Repair

Carelessness, rough handling, and disregard for safety rules cause premature explosions, misfires, and in many cases serious accidents. Demolition explosives and auxiliary items are packed to withstand general field conditions of transportation and storage in moisture-resistant containers and proper packing boxes. Containers and boxes must never be handled roughly; they must never be broken, cracked or dented. Some special items, if distorted, lose part of their effectiveness. Damaged packing boxes and containers must be repaired immediately; all defaced parts of marking must be transferred to new parts of the boxes. Broken airtight containers, such as those containing chemical mines, should be destroyed.

Table XVI. Minimum Safe Distances for Personnel in the Open

Pounds of explosive	Safe distance in feet	Pounds of explosive	Safe distance in feet
1–27	900	65	1,200
28	909	70	1,230
29	921	75	1,260
30	930	80	1,290
32	951	85	1,317
34	969	90	1,344
36	990	95	1,368
38	1,008	100	1,392
40	1,020	125	1,500
42	1,041	150	1,593
44	1,050	200	1,752
46	1,074	300	2,007
48	1,080	400	2,208
50	1,104	500	2,382
55	1,141	Over 500 (compute by formula)	
60	1,170		

Note. Chart is based upon formula: $d = 300$ 4Pp for charges from 27 to 500 pounds
d = safe distance in feet.
p = pounds of explosives.
In quarry blasting, 350 is the constant.

143. TNT and Tetrytol

TNT and tetrytol, which is a mixture of TNT and tetryl are relatively safe to handle. Fragments of TNT and tetrytol should not be accumulated but destroyed promptly.

144. Ammonium Nitrate and Nitramon Cratering Charges

The containers for the ammonium nitrate and nitramon cratering charges are easily punctured, permitting the rapid absorption of moisture and reduction in the explosive's effectiveness. Care must be taken in handling the container.

145. Shaped Charges

These are cast in a cone shape to increase their power. Cracks, breaks, or dents destroy this shape and thus decrease their effectiveness.

146. Commercial Dynamite

Commercial dynamite is more sensitive to heat and shock than any of the other commonly used explosives. The nitroglycerin it contains settles to the bottom and drains from the cartridge. To minimize this leakage, dynamite cases are stored so that the cartridges lay horizontally. Straight dynamite in cases, which also has a nitroglycerine leakage, should be turned as follows:

Below 30° F.	Not turned.
30°–60° F.	Every 6 weeks.
60°–75° F.	Monthly.
Over 75° F.	Every 2 weeks.

Commerical dynamite has depressants added to lower the freezing point and make it more reliable at low temperatures. Some types of commercial dynamite, however, originally made for use only in warm climates, may freeze under low temperature conditions.

147. Old Dynamite

Old dynamite may be recognized by the oily substance collected on the casing or by stains appearing on the wooden packing case. These are caused by the separation of the nitroglycerin from the porous base. Dynamite in this state, being extremely sensitive, must not be used but destroyed immediately by burning (TM 9–1900).

148. Frozen Dynamite

Frozen dynamite is recognized by its hardness and by the appearance of extremely sensitive crystals in the contents of the stick. Its use is not recommended. It may be destroyed by burning in the same manner as old dynamite. Frozen dynamite, may be used, however, if thawed (fig. 93), as follows:

a. Use a commercial thawing kettle similar to the one shown in figure 92. If this is not available, a 5- and a 10-gallon container may be combined to make a good substitute.

(1) Heat water in a separate container to a temperature as high as can be tolerated by the hand.

(2) Pour the heated water into the water compartment of the thawing kettle.

(3) Lay the frozen dynamite in the inner compartment in a horizontal position, with the bottom sticks supported on strips of wood or other material, so that the air can circulate readily around it.

(4) Place the kettle in a barrel or box insulated by hay or some other satisfactory material.

(5) Thaw no more than 50 pounds of frozen dynamite in a single lot.

(6) Never place the frozen dynamite in the thawing compartment of the kettle before the hot water is poured into the water compartment.

(7) Never set the kettle over heat after the dynamite has been placed in it.

b. Frozen dynamite is completely thawed when it has returned to its original consistency. This can be determined by squeezing the sticks lightly with thumb and forefinger. If no hard spots remain and when unwrapped no crystals are seen, it is thawed and ready for use.

149. Detonating Cord

Rules in handling and using detonating cord are as follows:

a. Avoid kinks and sharp bends.

b. Handle with special care to avoid breaking either the covering or the explosive train.

c. Lay lines out as straight as possible but not stretched taut. As detonating cord forms a spiral as it is unwound from the spool, it must be straightened out carefully before firing to avoid misfire.

d. Do not remove any part of the outer covering.

e. Apply sealing compound to the end to keep out moisture when the charge is placed underwater or left in place several hours before firing. A 6-inch free end protects the remainder of the line from moisture for 24 hours.

f. Use only the methods given in paragraphs 80 to 90 in making connections.

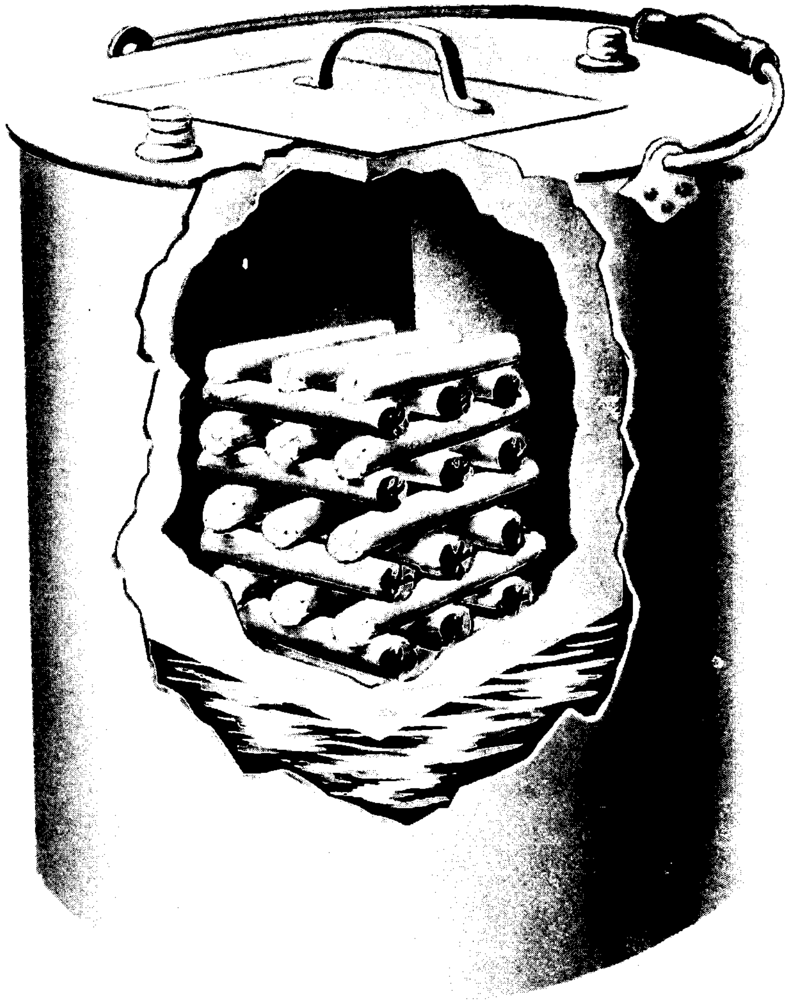


Figure 93. Dynamite thawing kettle.

150. Transportation

a. Safety Policy. Local transportation of explosives for immediate use is directed by AR 385–63. The Department of the Army clearly defines the safety responsibilities of transportation officers at their installations. Local safety SOP,s are provided to insure that all persons participating in the transportation of explosives have proper instruction in safety requirements and are held to account for all violations of procedure.

b. General Rules. The following rules are observed:

(1) Vehicles used for the transportation of explosives shall not be loaded beyond rated capacity and the explosives shall be so secured to prevent shifting of load or dislodgement from the vehicle in transit. In all open-body types of vehicles the explosives shall be covered with a fire-resistant tarpaulin.

(2) All vehicles transporting explosives shall be marked with reflectorized placards on both sides and ends with the word EXPLOSIVES in white letters not less than 8 inches high on a red background.

(3) Blasting caps or other exploders shall not be transported in the same vehicle with other explosives.

(4) All vehicles used for transportation of explosives shall be in charge of and operated by a person who is physically fit, careful, reliable, able to read and write the English language, and not addicted to the use of intoxicants or narcotics.

(5) No metal tools, carbides, oils, matches, firearms, electric storage batteries, flammable substances, acids, or oxidizing or corrosive compounds shall be carried in the bed or body of any vehicle transporting explosives.

(6) Vehicles to be used in the transportation of explosives shall be in good repair. When steel or part steel bodies are used, fire-resistant and nonsparking cushioning materials shall be employed to separate the containers of explosives from the metal.

(7) Vehicles transporting explosives shall be equipped with not less than two fire extinguishers, placed at strategic points, filled and ready for immediate use, and of a make approved by the National Board of Fire Underwriters for class B and C fires.

(8) A vehicle containing explosives shall not be taken into a garage or repair shop or parked in congested areas or stored overnight, or at any other time, in a public garage or similar building.

(9) All vehicles shall be checked before transporting explosives and all electric wiring completely protected and securely fastened to prevent short circuiting.

(10) Vehicles transporting explosives shall be operated with extreme care and shall not be driven at a speed greater than 35 miles per hour. Full stops shall be made at approches to all railroad crossings and main highways and the vehicle shall not proceed until it is known that the way is clear. This, however, does not apply to convoys.

(11) All vehicles transporting explosives on public highways, roads, or streets shall have an authorized driver and helper. No person other than the authorized driver and helper shall be permitted to ride on trucks transporting explosives or detonators.

151. Magazines

a. Types. Explosives are stored in magazines according to the safety regulations prescribed in TM 9–1903 because of their great potential destructive effects. Table XVII indicates the minimum distances for the location of magazines from other magazines, buildings, and routes of communication. There are two types of magazines—permanent and temporary. Although the permanent type is preferred, temporary or emergency types are frequently required when permanent construction is not possible.

b. Barricades. Explosive storage magazines must be barricaded, that is, have a substantial obstacle between them and inhabited buildings. For certain explosives, effective natural or artificial barricades reduce by one-half the distance necessary between magazines, railways, and highways. The use of barricades thus permits the storage of larger quantities of explosives in any given area. Although barricades help protect magazines against explosions and bomb or shell fragments, they are no safeguard against damage.

c. Other Considerations. Magazines are usually placed at locations, determined according to safety, accessibility, dryness, and drainage. Safety and accessibility, however, are the most important. An ideal location is a hilly area where the height of the ground above the magazine provides a natural wall or barrier to buildings, centers of communication, and other magazines in the area. Sidehill dugouts are not desirable, as adequate ventilation and drainage are often hard to provide. Brush and tall grass should be cleared from the site to minimize the danger of fire.

Table XVII. Magazine Locations (Unbarricaded)

Quantity, pounds of explosives (not over)	Minimum distance in feet from nearest—		
	Inhabited building	Magazine	Public highway, railway, and/or electric lines
50	300	50	180
100	380	50	230
2,000	1,010	140	610
20,000	1,950	300	1,170
100,000	3,630	510	2,180
225,000	4,190	670	2,515

Note. For more detailed information see TM 9-1903, C 1, 26 February 1957.

d. Lightning Protection. All magazines must have an overhead lightning rod system. Also, all metal parts—doors, ventilators, window sashes, and reinforcing steel—must be connected in several places to buried conduits of copper plate or graphite rods.

152. Field Expedient Structures

a. Field expedients for the storage of explosives when magazine construction is not possible are—

(1) A dugout excavated in a dry bluff and timbered to prevent caving.

(2) An isolated house or an isolated shed.

(3) A light wooden frame box house, with a wedge type roof covered by corrugated iron, or merely covered with a tent or canvas tarpaulin.

b. Field expedient storage facilities should be appropriately marked by signs on all four sides, and guarded.

153. Temporary Magazines and Storage

Limited supplies of explosives can be stored for several days when necessary in covered ammunition shelters and should be so separated that fire or explosion cannot be transmitted from one shelter to another. Piles of explosives temporarily stored in the open should contain no more than 500 pounds, if practical, and be placed no less than 140 feet apart. Explosive components should be piled separately. Explosives, caps, and other demolition material stored temporarily in training areas should be kept in covered ammunition shelters, if possible, and under guard at all times. Temporary storage operations should be guided by local safety SOP's and other regulations.

154. Destruction and Disposal of Explosives

Explosives, being insoluble in water, generally cannot be disposed of as sewage. Submergence, burning, or decomposition by chemical agents is necessary. Explosive material may be disposed of without alteration in form by dumping at sea. The best method of destroying explosives, however, is by burning, excepting blasting caps, which are detonated if in quantity and decomposed chemically, if in smaller amounts. Large quantities of explosives are destroyed by explosive ordnance disposal units as directed in AR 75–15, TM 9–1385–9, TM 9–1900, and TM 9–1903.

APPENDIX I
REFERENCES

DA Pam 27–1	Treaties Covering Land Warfare.
DA Pam 310–1	Index of Administrative Publications.
DA Pam 310–4	Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrication Orders, and Modification Work Orders.
AR 75–15	Responsibilities and Procedures for Explosive Ordnance Disposal.
AR 320–5	Dictionary of United States Army Terms.
AR 320–50	Authorized Abbreviations and Brevity Codes.
AR 385–63	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
SM 9–5–1375	Stock List of Current Issue Items–FSC Group 13 Ammunition and Explosives, Class 1375 Solid.Propellants, and Explosive Devices.
FM 5–31	Use and Installation of Boobytraps.
FM 5–34	Engineer Field Data.
FM 8–10	Medical Service, Theater of Operations.
FM 20–32	Land Mine Warfare.
FM 31–10	Barrier and Denial Operations.
TM 5–220	Passage of Obstacles Other than Minefields.
TM 5–280	Foreign Mine Warfare Equipment.
(C) TM 5–280A	Foreign Mine Warfare Equipment (U).
TM 5–332	Pits and Quarries
TM 5–335	Drainage Structures, Subgrades, and Base Courses.
TM 9–1375–203–12	Operator and Organizational Maintenance Manual: 10-Cap Capacity Handle Operated Blasting Machine.
TM 9–1385–9	Explosive Ordnance Reconnaissance.
TM 9–1900	Ammunition, General.
TM 9–1903	Care, Handling, Preservation, and Destruction of Ammunition.
TM 9–1910	Military Explosives.
TM 9–1940	Land Mines.
TM 9–1946	Demolition Materials.
GTA 5–14	Demolition Card.

APPENDIX II
METRIC CALCULATIONS

1. Introduction

The following metric formulas are included because of NATO requirements, wherein the United States and British Armies are gradually changing over from their tables of measurement to the metric system. Problems, solutions, and tables with measurements converted to the metric system are found below.

2. Structural Steel Cutting Formula

Formula: $K = \frac{A}{38}$

K = kilograms of TNT required.

A = cross sectional area in square centimeters.

Example: (fig. 61)

Flange Area = 2×1.2×12.7 = 30.48 or 30.5 sq. cm.

Web Area = 28×1 = 28 sq. cm.

A (total) = 30.5 sq. cm. + 28 sq. cm. = 58.5 sq. cm.

$K = \frac{A}{38} = \frac{58}{38}$

K = 1.5 (use 1.5 kilograms of TNT)

3. Timber-Cutting Formula

a. External Charge.

Formula: $K = \frac{D^2}{550}$

K = kilograms of TNT required.

D = diameter of target in centimeters.

Example: the diameter of a tree is 30 centimeters.

$K = \frac{30^2}{550} = \frac{900}{550}$

K = 1.64 kg.

Use of 1.6 kilograms of TNT.

b. Internal Charge.

Formula: $K = \frac{D^2}{3500}$

K = kilograms of TNT required.

D = diameter of target in centimeters.

Example: (fig. 60)

$K = \frac{D^2}{3500}$

$K = \frac{30^2}{3500} = \frac{900}{3500}$

K = .257 kg.

Use 260 grams of TNT.

4. Breaching Formula

Formula: $K = 16R^3KC$

K = kilograms of TNT required.

R = breaching radius in meters.

K = the material factor based on strength and hardness of material to be demolished.

C = the tamping factor based on type and extent of tamping to be used.

Add 10% to calculated charges less than 22.5 kilograms.

Table XVIII. Values of Material Factor K for Calculation of Breaching Charges

Material	Breaching radius	K
Ordinary earth	All values	0.05
Poor masonry, shale and hardpan, good timber, and earth construction	All values	0.23
Good masonry, ordinary concrete, rock	Less than 1 meter	0.35
	1 to less than 1.5 meters	.28
	1.5 to less than 2 meters	.25
	More than 2 meters	.23
Dense concrete, first-class masonry	Less than 1 meter	0.45
	1 to less than 1.5 meters	.38
	1.5 to less than 2 meters	.33
	2 or more meters	.28
Reinforced concrete (will not cut steel reinforcing)	Less than 1 meter	0.70
	1 to less than 1.5 meters	.55
	1.5 to less than 2 meters	.50
	2 or more meters	.43

a. Breaching Radius. The breaching radius (R) is the distance in meters which an explosive charge must penetrate and within which all material is displaced or destroyed. For example, to break a 2-meter concrete wall by placing a charge on one side, the value of R in the formula $K=R^3KC$ is 2 meters.

b. Material Factor. The values of the material factor for various types of construction are given in table XVIII.

c. Tamping Factor. The value of the tamping factor depends on the location and the tamping of the charge. No charge is considered fully tamped unless it is covered to a depth equal to the breaching radius. If underwater demolition is essential, the tamping factor for placement of charges in air is used.

Example: Determine the amount of TNT required to breach a reinforced concrete pier two meters thick with untamped charges placed on the ground.

$R=2$ meters.

$K=.50$ (reinforced concrete, table XVIII).

$C=4.5$ (untamped, on the ground).

$K=16R^3KC$.

$K=16\times 8\times .50\times 4.5$

$K=288$ kilograms of TNT per charge.

Table XIX. Characteristics of Principal U. S. Explosives (Metric)

Name	Velocity of detonation (meters per sec)	Relative effectiveness	Weight per block
TNT	6,400	1.00	.454 and .227 kg
Tetrytol	7,000	1.20	1.1 kg
Composition C-3	7,925	1.34	1.02 kg
Composition C-4	7,925	1.34	1.1 kg
Ammonium nitrate	3,352	0.42	18.17 kg
Military dynamite	6,096	0.92	.227 kg

Table XX. Pressure Charges (Weight of TNT)

Weight of explosive for each beam (tamped charges) in kilograms									
Height of beam in meters	Thickness of beam in meters								
	0.30	0.38	0.46	0.53	0.61	0.69	0.76	0.84	0.91
0.30	1.4								
0.38	2.3	2.7							
0.46	3.2	4.0	5.0						
0.53	4.5	5.4	6.4	7.3					
0.61	5.4	6.8	8.2	9.5	10.9				
0.69	7.3	8.6	10.4	12.2	14.1	15.9			
0.76	8.6	10.9	13.2	15.0	17.2	19.5	21.3		
0.84	10.4	13.2	15.4	18.1	20.9	23.1	25.9	28.6	
0.91	12.2	15.4	18.6	21.8	24.5	27.7	30.8	34.0	36.7
0.99	14.5	18.1	21.8	25.4	29.0	32.7	36.3	39.9	43.1
1.07	16.8	20.9	25.4	29.5	33.1	37.6	41.7	45.8	50.5
1.14	19.5	24.0	29.0	33.6	38.6	43.1	48.0	52.6	57.6
1.22	21.8	27.2	32.7	38.1	43.5	49.0	54.4	60.0	65.4
1.30	24.9	30.8	37.2	43.1	49.4	55.3	61.7	67.6	74.0
1.37	27.7	34.5	4.7	48.5	55.4	62.1	68.9	75.8	83.2
1.45	30.8	38.6	46.3	54.0	61.8	69.4	77.1	84.8	92.0
1.52	34.0	42.7	51.3	60.3	68.0	76.7	85.2	94.0	102.0

Table XXI. Steel Cutting Charges

Average thickness of section in centimeters	Kilograms of TNT for rectangular steel sections of given dimensions												
	Width of Sections in Centimeters												
	5.0	7.6	10.2	12.7	15.2	20.3	25.4	30.5	35.6	40.6	45.7	50.8	61.0
.64	.09	.14	.18	.23	.27	.36	.45	.54	.64	.73	.82	.91	1.1
.95	.14	.23	.27	.32	.41	.54	.64	.77	.91	1.04	1.18	1.27	1.54
1.27	.18	.27	.36	.45	.54	.68	.86	1.04	1:22	1.36	1.5	1.7	2.0
1.59	.23	.32	.45	.54	.64	.86	1.1	1.32	1.5	1.7	1.95	2.13	2.59
1.91	.27	.41	.54	.64	.77	1.00	1.27	1.54	1.81	2.04	2.31	2.59	3.08
2.22	.32	.45	.64	.77	.90	1.22	1.5	1.81	2.08	2.4	2.7	3.0	3.6
2.54	.36	.54	.68	.86	1.04	1.36	1.7	2.0	2.4	2.7	3.1	3.4	4.1

Table XXII. Minimum Safe Distances (in the Open)

Kilos of explosives	Safe distance in meters	Kilos of explosives	Safe distance in meters
.45 to 12 kilos	274	34	384
13	281	36	393
14	290	40	410
16	302	45	424
18	311	56	457
20	320	62	486
22	329	90	534
23	337	136	612
25	348	181	673
27	357	226	726
29	366	Over 226 (compute by formula)	

APPENDIX III

USE OF LAND MINES, AERIAL BOMBS, AND SHELLS AS DEMOLITION CHARGES

1. Introduction

When land mines, aerial bombs, and shells are used as demolition charges, special precautions must be taken because of flying steel fragments. The use of such mines, bombs, and shells is generally uneconomical but may at times become necessary or desirable. Such material may be issued from captured or friendly supply stocks or, in the case of land mines, may be those recovered from enemy or friendly minefields. *In no case should unexploded dud shells or bombs be used for demolition purposes.*

2. Land Mines

a. Safety Precautions. Only defuzed mines should be used in demolition charges, as fuzed mines recovered from minefields may be sensitive because of near misses and may be detonated by even normal handling. The use of enemy mines salvaged from minefields or dumps is regulated by directives issued from headquarters of the theater concerned. United States and foreign land mines are described in detail in FM 20–32, TM 5–280, and TM 5–280A.

b. Charges. In calculating demolition charges when using mines, only the explosive weight is considered. Normal explosive quantities may be used for cratering or pressure charges with mines; but, because of poor contact of the mine case against irregularly shaped objects, it may be necessary to increase cutting charges considerable. Test shots will determine the results to be expected under given conditions.

c. Priming. Land mines are detonated by exploding a pound of explosive on the pressure plate. If large quantities of mines are to be fired simultaneously, several mines are primed to insure complete detonation. Detonation of a single mine normally detonates other mines in contact with it.

3. Aerial Bombs

a. Use. General-purpose aerial bombs may be used satisfactorily as demolition charges but are more effective as cratering charges. Their shape makes them inefficient for demolitions requiring close contact between the explosive and the target. Precautions must be taken to avoid damage to installations and injury to personnel because steel fragments of the bomb case are thrown great distances. Before using a bomb it must be positively identified as a general-purpose bomb.

b. Charges. The explosive content of bombs is approximately half their total weight. Table XXIII gives the weight of high explosive in various types of general-purpose bombs. Approximately 20 percent of the explosive power is expended in shattering the case.

c. Priming. Bombs under 500 pounds weight are detonated by firing a 5-pound explosive charge in good contact in the middle of the case. Bombs of 500 pounds or more are detonated by a 10-pound charge similarly placed. Fuzes should not be put in the bombs and detonating charges should not be positioned on the nose or tail. To insure detonation, large bombs should be primed separately.

4. Artillery Shells (Nonnuclear)

Artillery shells are used for demolition only where a fragmentation effect is desired. Because of their low explosive content they are seldom used for other demolition purposes. The 105-mm howitzer HE shell which weighs 33 pounds, contains only 5 pounds

Table XXIII. Explosive Content of General-Purpose Bombs

Bomb	Total weight (lb)	Explosive weight (lb)
100-lb GP, AN-M30A1	115	57
250-lb GP, AN-M57A1	260	125
500-lb GP, AN-M64A1	525	266
1,000-lb GP, AN-M65A1	990	555
2,000-lb GP, AN-M66A2	2,100	1,098
3,000-lb GP, T-55	2,605	1,710

of explosive; while the 155-mm howitzer HE shell contains only 15 pounds. Shells up to 240-mm are detonated by 2 pounds of explosive placed in good contact with the case, just forward of the rotative band. To insure complete detonation, a charge should be placed on each shell. The universal destructor M10 (par. 36*a*) may be used to detonate projectiles or bombs that have 1.7- or 2-inch diameter threaded fuze wells. The booster cavities of bombs and large projectiles should be filled to the full depth by adding booster cups to the destructor M10 as required.

APPENDIX IV

SUMMARY OF EXPLOSIVE CALCULATION FORMULAS

1. Steel-Cutting

a. Structural Members (par. 76*b*(1)).

$P = \frac{3}{8} A$

P = pounds of TNT required

A = cross-sectional area in square inches of the steel member to be cut.

b. Other Steel Members (par. 76*b*(2)).

$P = D^2$

P = pounds of TNT required.

D = diameter, in inches, of section to be cut.

c. Railroad Rails.

To cut 80-pound or lighter rail, use ½ pound of explosive. To cut rails over 80 pounds, use 1 pound of explosive.

2. Timber-Cutting Charges

a. External Charges, Untamped (par. 71*a*).

$P(\text{TNT}) = \frac{D^2}{40}$

$P(\text{TNT})$ = pounds of TNT required

D = diameter of the timber in inches or the least dimension of dressed timber.

b. Internal Charges, Tamped (par. 71*c*).

$P = \frac{D^2}{250}$

P = pounds of explosive required.

D = diameter, or least cross-sectional dimension in inches.

c. Cutting Trees to Create an Obstacle (par. 71*c*).

$P = \frac{D^2}{50}$

3. Pressure Charges to Destroy Simple Span Reinforced Concrete T-Beam Bridges

(par. 81).

$P = 3H^2T$

P = pounds of TNT required for each stringer.

H = height of stringer, including thickness of roadway in feet.

T = thickness of stringer in feet.

The values of H and T, if not whole numbers, are rounded off to the next higher quarter-foot dimension. Neither H nor T is ever considered to be less than 1 in the formula.

Note. Increase the calculated charge P by one-third if it is not tamped.

4. Breaching Charges

a. Size of Each Charge (par. 86*a*, *b*).

$P = R^3KC$

P = pounds of TNT required.

R = breaching radius in feet.

K = material factor (table VII).

C = tamping factor (fig. 66).

Note. Add 10 percent to the calculated charge whenever P is less than 50 pounds and increase the charge by 5 percent for walls 1 foot thick or less.

b. Number of Charges (par. 87*b*).

$N = \frac{W}{2R}$

N = number of charges.

W = width of pier, slab, or wall, in feet.

R = breaching radius, in feet.

When the value of N has a fraction less than ½, the fraction is disregarded, but when the fraction is ½ or more, the value is rounded off to the next higher whole number. An exception to the general rule is the N-value between 1 and 2, wherein a fraction less than ¼ is disregarded, but a fraction of ¼ or more is rounded off to the next higher whole number, 2.

5. Cratering Charges

a. Deliberate Method (par. 91). Forty-pound charges in 5-foot boreholes are alternated with 80-pound charges in 7-foot boreholes. All boreholes are placed on 5-foot centers. The end holes in all cases are 7 feet deep. No two 5-foot holes should be adjacent to each other.

b. Hasty Method (par. 92). Ten pounds of explosive per foot of borehole is placed in holes of equal depth. Boreholes are positioned on 5-foot centers at depths varying from 2½ to 5 feet.

6. Breaching Hard-Surfaced Pavements

(par. 89*b*(2)).

Charges are computed on the basis of 1 pound of explosive per 2 inches of pavement thickness. Tamping should be twice the thickness of the pavement.

7. Computation of Minimum Safe Distances

(par. 141)

a. For charges of 27 pounds or less, the minimum safe distance is 900 feet. This, however, gives no insurance against missile hazards, which require a defilade.

b. For charges from 27 to 500 pounds, the safe distance is computed by means of this formula:

$$\text{Safe distance in feet} = 300 \sqrt[3]{\text{pounds of explosive}}.$$

8. Notes

a. The charges calculated by the above formulas should be rounded off to the next higher unit package of explosive being used.

b. When an explosive other than TNT is used in external charges computed from the steel, timber, breaching, or pressure formula, the value of P should be adjusted as indicated in table IV.

APPENDIX V

POWER REQUIREMENTS FOR MULTIPLE FIRING CIRCUITS

1. Circuits

In smaller demolition projects electric blasting caps are usually connected in series and fired by an electric blasting machine (par. 37*c*). If, however, a project requires a voltage for the simultaneous explosion of more separately primed charges higher than the rated capacity of the blasting machine, the circuit must be fired by some other power source. If the voltage required to fire a great many caps connected in series is much higher than that of any available power source, other circuits must be used in order to reduce voltage requirements. The types of circuits are—

a. Series Circuit. A series circuit provides but one path for the electrical current which flows from one firing wire through each blasting cap to the next blasting cap and back to the other firing wire. A series circuit should not contain more than 50 blasting caps. The connection of an overload of caps in a circuit increases the hazard of cutoffs in the firing line or cap leads prior to the initiation of some caps.

b. Parallel Circuit. A parallel circuit consists of a pair of main wires (called bus wires) and a pair of firing wires, with each blasting cap connected across this pair. One lead of the cap is attached to one bus wire, and the other lead of the cap is attached to the other. Only *balanced* parallel circuits should be used in blasting. A balanced circuit is one in which each branch of the parallel system is electrically just like every other branch. This is obtained by using identical caps throughout a given parallel system.

c. Series-Parallel Circuit. A series-parallel circuit consists of a number of separate series-connected groups of blasting caps joined in parallel. Thus a series-parallel system is much like a parallel system except that the separate parallel branches are made up of a series-connected group of blasting caps, rather than each branch being a separate blasting cap. Only *balanced* series-parallel circuits should be used in blasting. Balance may be obtained by using the same number of identical blasting caps in each branch, providing that connections, secondary leads and cap leads introduce only a negligible amount of resistance or equal resistance. Where the quantities of explosives are considerable, long leads should be used to connect the series-connected branch of caps to the main wires of the circuit in order to reduce the chance of the main wires being cut by the charge before the current reaches the end of the parallel circuit. No more than 30 blasting caps should be connected in any single branch of a series-parallel circuit.

2. Precautions

Observe the following rules in all parallel or series-parallel circuits.

a. Connect no more than one type or make of caps in a circuit.

b. Connect not more than 30 caps in each series-connected branch of a series-parallel circuit.

c. When two or more series are connected in parallel, place the same number of caps in each branch.

d. Give particular attention to rules *b* and *c* when the wiring has been accomplished in several stages and then joined to form a circuit. If several series arrangements are joined in series, check to see that there are no more than 30 caps in the entire series-connected branch (rule *b*). If several parallel arrangements are connected in parallel, they are very likely to be out of balance. Such circuits should be avoided because they are very difficult to check for balance. Connect separate series stages in parallel to make a series-parallel circuit.

e. In series-parallel circuits, use lead wires identical and approximately the same length. Make all connections tight, because loose or faulty connections increase resistance greatly, thereby causing unbalanced eircuits and cause misfires.

f. Use direct current if possible. Alternating current may be used, but it should be at least 25 cycle and preferably 50 cycle or more.

***Caution:* In parallel and series-parallel circuits, one or more branches of the circuit may not fire when the charge is exploded. Take great care during post-firing inspection to locate and destroy all unexploded parts of the circuits. These circuits, however, should not be used except by an experienced demolition specialist.**

3. OHM'S Law

The amount of voltage necessary to detonate the blasting caps in these circuits is calculated by the use of the basic law of electricity, Ohm's Law:

$E=IR$

E=electrical potential, or voltage, expressed in volts.

I=current, expressed in amperes.

R=resistance, expressed in ohms.

4. Electric Power Formula

Electrical power is computed by means of the following formula:

$W=I^2R$

W=electrical power, expressed in watts.

I=current, expressed in amperes.

R=resistance, expressed in ohms.

5. Electrical Characteristics of Electric Blasting Caps

The current needed to fire military electric blasting caps connected in series should be at least 1.5 amperes regardless of the number of caps. In a parallel circuit the current should be at least 0.6 ampere per blasting cap. The resistance of a military electric blasting cap is 2 ohms.

6. Resistance of a Circuit

This is computed to insure that the power source is adequate to fire all charges connected to the circuit. Both the blasting caps and the wire contained in a circuit contribute to the total resistance of that circuit. This resistance is computed from the individual resistances of the blasting caps and the wire. Computation is not the same, however, for different types of circuits. The resistance of the wire used in a circuit depends upon its size and the length. Table XXIV gives the resistance *per 1,000 feet* of various sizes of copper wire.

a. Total Resistance in a Series Circuit. The total resistance in a series circuit is the sum of the resistances of the various components of that circuit. (For simplicity of calculation in the field, only the resistance of the blasting caps is used to determine the resistance of a circuit. The wires comprising a particular type of circuit are not included in the resistance of that circuit but in the overall system as explained in *b*, below.) The total resistance in a series circuit, or the total resistance in one series-connected branch of a series-parallel circuit, is computed by simply adding the resistance of all the caps and wire that comprise that series circuit or the series-connected branch of the series-parallel circuit.

b. Total Resistance of a Balanced Parallel Circuit. The resistance of a parallel circuit is less than that of a series circuit comprised of the same elements. Because the electricity has more paths through which to flow, the same voltage will push more amperes of current through the parallel system. If Ohm's Law is to hold true, the resistance of the entire system must be less. The total resistance of a balanced parallel system of electric blasting caps is equal to the resistance of one branch (2 ohms, since a branch consists of only one cap) divided by the number of branches (*a* above). To this value must be added the resistance of the wires connecting the parallel system with the power source. It is customary to include the resistance of only one-half of the length of the bus wires but to include the resistance of the total length of the firing wires.

c. Total Resistance of a Balanced Series-Parallel Circuit. The resistance of a single branch of a series-parallel circuit is computed as stated in *a* above. After computing the resistance of a single branch, compute the resistance of the entire circuit as outlined in *b* above, using the resistance in one branch rather than the resistance of one blasting cap as the figure to be divided by the number of branches.

Table XXIV Resistance of Various Sizes of Copper Wire

1	2	3	4
Size of copper wire			Resistance of 1,000 feet of wire (ohms per 1,000 ft)
AWG (B&S) gage No.	Diameter (in.)	Length of wire to weigh 1 pound (ft per lb)	
2	3/10	5.0	0.2
4	1/4	7.9	.3
6	1/6	12.6	.4
8	1/8	20.0	.6
10	1/10	31.8	1.0
12	1/12	50	1.6
14	1/16	80	2.5
16	1/20	128	4.0
18	1/25	203	6.4
20	1/30	323	10.2

7. Calculations for a Series Circuit

Complete calculations for any circuit involve the determination of the current (amperes), the voltage (volts), and the power (watts) needed to fire the circuit. Computation of the voltage and of the power requires the determination of the resistance (ohms) in the system.

a. Current Requirements. The current required for a series-connected system of special electric blasting caps is 1.5 amperes, regardless of the number of blasting caps in the circuit.

b. Resistance. The resistance of the system is computed as described in paragraph 6*a* of this appendix.

c. Voltage Requirements. Using Ohm's Law, $E=IR$ (par. 3 this app.), the voltage needed is computed by multiplying the required current (1.5 amperes) by the resistance of the system.

d. Power Requirements. By means of the electrical power formula, $W=I^2R$ (par. 4 this app.), the number of watts of power needed may be found by multiplying the square of the current required ($1.5^2=2.25$) by the resistance of the system.

e. Illustrative Problem. Determine the current, voltage, and power required to detonate the blasting caps of a circuit consisting of 20 special electric blasting caps connected in series, and 500 feet of the standard 2-conductor, 18-gage firing wire.

(1) Current required = 1.5 amperes (*a* above)

(2) Resistance:

20 blasting caps $=2.0\times20$	$=40$
1,000 feet No. 18 wire (table)	$=6.4$
Total resistance	$=46.4$ ohms

Note. As 500-foot firing wire consists of 2 strands of No. 18 wire each 500 feet long, 1,000 feet of wire is used in the above computation.

(3) Voltage:

$E=IR$ (par. 3 this app.)

$E=1.5\times46.4=69.6$ volts

(4) Power:

$W=I^2R$ (par. 4 this app.)

$E=1.5^2\times46.4=2.25\times46.4=104.4$ watts

8. Calculations for a Parallel Circuit

The current required for a parallel circuit of special electric blasting caps is 0.6 ampere per blasting cap. This is expressed by the following formula:

a. Current:

$I=0.6N$ (*a* above)

$I=0.6\times20=12$ amperes

b. Resistance (refer to table XXIV for wire resistances):

Firing wire	$=\frac{800}{1,000}\times6.4$	$=5.1$ ohms
Bus wires	$=\frac{380}{1,000}\times10.2\times\frac{1}{2}$	$=2.0$ ohms
Blasting caps	$=2.0\div20$	$=0.1$ ohms
Total resistance		$=7.2$ ohms

c. Voltage:

$E=IR$

$E=12\times7.2=86.4$ volts

d. Power:

$W=I^2R$

$W=12^2\times7.2=144\times7.2=1,037$ watts

Note. The length of the firing wire is computed as shown in paragraph 7*e*(2) of this appendix. The length of the bus wires is computed by multiplying the 10-foot interval length by the 38 intervals between the 20 charges (19 intervals on each bus wire). The resistance of the bus wires is then multiplied by ½ as indicated in paragraph 6*b* of this appendix.

9. Calculations for a Series-Parallel Circuit

a. Current Requirements. The current required in this circuit of military blasting caps is 1.5 amperes per circuit branch according to the following formula:

$I=1.5N$

$I=$ total current

$N=$ number of separate series-connected branches that are parallel

b. Resistance. The resistance of a series-parallel circuit is computed as indicated in paragraph 6 of this appendix.

c. Voltage Requirements. This is computed by means of Ohm's Law ($E=IR$), or by multiplying the required current by the resistance of the system.

d. Power Requirements. This is computed by means of the electrical power formula ($W=I^2R$), or by multiplying the square of the required current by the resistance of the system.

e. Illustrative Problem. Compute the current, voltage, and power requirements for detonating a system of 300 military electric blasting caps in a series-parallel circuit composed of 10 branch lines. Each branch line has 30 military electric blasting caps connected in series. The wiring consists of 400 feet of 20-gage bus wire and 500 feet of standard 18-gage, 2-conductor firing wire.

(1) Current (*a* above):

$I=1.5N$

$I=1.5\times10=15$ amperes

(2) Resistance:

(*a*) Each series $=30\times2=60$ ohms

Table XXV. *Maximum Circuit Capacities of Various Power Sources*

1	2	3	4	5	6	7	8	9	10
		Power source							
Circuit design	Total number of caps in circuit	10-cap blasting machine	30-cap blasting machine	50-cap blasting machine	1½-kw portable generator, 115-volt, 13½-amp	3-kw portable generator, 115-volt, 26-amp	5-kw portable generator, 115-volt, 43½-amp	3-kw portable generator, 220-volt, 13½-amp	5-kw portable generator, 220-volt, 22½-amp
		The circuits below are connected by one 500-foot standard two-conductor firing reel							
1 10 caps in continuous series	10	x	x	x	x	x	x	x	x
2 30 caps in continuous series	30	--------	x	x	x	x	x	x	x
3 50 caps in continuous series	50	--------	--------	x	--------	--------	--------	x	x
		The circuits below are connected with one 500-foot standard two-conductor firing reel and 200-feet of 20-gage connecting wire							
4 2 series with 30 caps each	60	--------	--------	--------	x	x	x	x	x
5 4 series with 23 caps each	92	--------	--------	--------	x	x	x	x	x
6 6 series with 16 caps each	96	--------	--------	--------	x	x	x	x	x
7 4 series with 30 caps each	120	--------	--------	--------	--------	--------	--------	x	x
8 6 series with 30 caps each	180	--------	--------	--------	--------	--------	--------	x	x
9 8 series with 30 caps each	240	--------	--------	--------	--------	--------	--------	x	x
10 15 series with 17 caps each	255	--------	--------	--------	--------	--------	--------	--------	x
11 9 series with 30 caps each	270	--------	--------	--------	--------	--------	--------	x	x
12 10 series with 30 caps each	300	--------	--------	--------	--------	--------	--------	--------	x
13 12 series with 30 caps each	360	--------	--------	--------	--------	--------	--------	--------	x
		The circuits below are connected with two 500-foot standard two-conductor firing reels and 400-feet of 20-gage connecting wire							
14 4 series with 8 caps each	32	--------	--------	--------	x	x	x	x	x
15 2 series with 23 caps each	46	--------	--------	--------	x	x	x	x	x
16 8 series with 13 caps each	104	--------	--------	--------	--------	--------	--------	x	x
17 6 series with 27 caps each	162	--------	--------	--------	--------	--------	--------	x	x

(*b*) Entire system:

Branches $= 60 \div 10 = 6$ ohms

Firing wire $= 6.4$ ohms

Bus wire $= \frac{400}{1{,}000} \times \frac{1}{2} \times 10.2 = 2.0$ ohms

Total resistance of the system. $= 14.4$ ohms

(3) Voltage:

$E = IR$ (par. 3 this app.)

$E = 15 \times 14.4 = 216$ volts

(4) Power:

$W = I^2R$ (par. 4 this app.)

$W = 15^2 \times 14.4 = 225 \times 14.4 = 3{,}240$ watts

10. Calculated Voltage Drop

In each of the examples given above the voltage drop (IR) in the blasting circuit was calculated by the use of Ohm's Law. In practice, if the calculated voltage drop exceeds 90 percent of the available voltage it is recommended that the resistance of the circuit be decreased or the voltage be increased.

11. Capacity of Power Sources

a. Determining Capacity of Power Sources. It is possible to determine from the nameplate amperage and voltage rating whether the power source is suitable for firing an electric circuit computed by the above methods. Frequently, however, the size of a circuit that may be fired with current from a given power source may be determined by consulting table XXV which gives the maximum capacities of various power sources. If it is necessary to calculate the capacity of a given generator from the nameplate data, proceed as follows:

(1) Divide the amperage of the power source by 1.5 to find the number of separate series-connected branches that may be hooked in parallel.

(2) Divide 90 percent of the voltage of the generator (par. 10, this app.) by the total amperage of the circuit (1.5×number of separate series-connected branches hooked in parallel) to determine the maximum resistance in ohms that may be in the circuit.

(3) Subtract the firing-reel and connecting-wire resistance from the maximum allowable circuit resistance of caps to determine the maximum allowable resistance of the caps in the circuit.

(4) To calculate the maximum number of caps per series-connected branch, multiply the allowable resistance of the caps in the circuit by the number of series-connected branch and divide by the resistance of one cap (2.0 ohms).

b. Illustrative Problem. Determine the number of military electric blasting caps that may be fired by a 3-kw, 220-volt, 13½-ampere generator and how the circuit should be arranged assuming that 500 feet of standard 2-conductor firing wire and 200 feet of 20-gage connecting wire are used.

(1) Number of series to be included in circuit $=\frac{13.5}{1.5}=9$

(2) Allowable resistance of circuit $=\frac{.90\times 220}{1.5\times 9}$ $=14.6$ ohms

(3) Resistance of firing wire = 6.4 ohms

(4) Resistance of connecting wire $\times\frac{1}{2}=\frac{200\times 10.2}{1{,}000}=1.0$ ohms

Total resistance of wire = 6.4+1.0 = 7.4 ohms

(5) Allowable resistance of caps for a series-parallel circuit = 14.6−7.4 = 7.2 ohms

(6) Number of blasting caps per series-connected branch $=\frac{9\times 7.2}{2}=32.4$ caps per series. Since no more than 30 caps should be connected in each series-connected branch, the circuit should be arranged in 9 series of 30 caps each, in parallel (par. 2*b*, this app.).

c. Use of Storage Batteries and Dry Cells. The size of a circuit that may be fired by a battery or dry cell may be determined by following the same procedure as that outlined in *a*(1) through (4), above.

***Caution:* For safety, disconnect the battery terminal prior to disassembly of the equipment where there is danger from shorting across the battery circuit. In reassembly, make the battery terminal connection last.**

APPENDIX VI
ADVANCED AND EXPEDIENT DEMOLITION TECHNIQUES

1. Use of Advanced Demolition Techniques

These techniques are not presented as a replacement of the present standard demolition methods but are recommended for use in special demolitions projects. Availability of trained personnel, time, and material will generally determine their use.

2. Steel-Cutting Charges

Three types of steel cutting charges are available for use—the saddle charge, diamond charge, and ribbon charge. Their effectiveness is improved by wrapping them in aluminum foil or heavy paper provided that not more than one thickness of the wrapper lies between the explosive and the target.

a. Saddle Charge. This charge is used on solid cylindrical, mild steel targets up to 8 inches in diameter. Detonation is initiated at the apex of the long axis (fig. 94).

(1) *Size of charge.*

(*a*) Base = $\frac{1}{2}$ the circumference of target.

(*b*) Long axis = 2 times the base.

(*c*) Thickness = $\frac{1}{3}$ of the thickness of block of plastic explosive for targets up to 6 inches in diameter; $\frac{1}{2}$ the thickness of block of plastic for targets from 6 to 8 inches in diameter.

(2) *Example.* Determine the dimensions of a charge for cutting a shaft 18 inches in circumference.

(*a*) Base $\frac{1}{2} \times 18 = 9$ inches.

(*b*) Long axis $= 2 \times 9 = 18$ inches.

(*c*) Thickness = $\frac{1}{3}$ thickness of block of plastic.

Note. Steel alloy targets over 9 inches in diameter require the diamond charge.

(3) *Placement.* The long axis of the saddle should be parallel with the long axis of the target. Detonation is by the placement of a military electric or nonelectric blasting cap at the apex of the long axis of the charge.

b. Diamond Charge. This is used on high carbon steel or steel alloy targets (fig. 95). It is shaped like a diamond.

(1) *Size of charge.* The size of the charge depends on the dimensions of the target.

(*a*) Long axis = circumference of the target.

(*b*) Short axis = $\frac{1}{2}$ the circumference of the target.

(*c*) Thickness = $\frac{1}{3}$ the thickness of block of plastic explosive.

(2) *Example.* Determine the size of a charge for cutting a steel alloy shaft 15 inches in circumference.

(*a*) Long axis = 15 inches.

(*b*) Short axis $= \frac{1}{2} \times 15 = 7\frac{1}{2}$ inches.

(*c*) Thickness = $\frac{1}{2}$ the thickness of block of plastic explosive.

(3) *Placement.* Wrap the explosive completely around the target so that the ends of the long axis meet. Detonate the charges simultaneously from both short axis ends. The best means of doing this is to crimp a nonelectric blasting cap to two pieces of detonating cord of the *same length.* Detonate the cord with an electric or nonelectric cap.

c. Ribbon Charge. This charge, if properly calculated and placed, cuts steel with considerably less explosive than standard charges. It is effective on noncircular steel targets up to 2 inches thich (fig. 96).

(1) *Calculation.* The effectiveness of the blast depends on the width and thickness of the explosive.

(*a*) *Thickness* of charge $= \frac{3}{4} \times$ the thickness of the metal.

(*b*) *Width* of charge $= 3 \times$ the thickness of the charge.

(*c*) *Length* of charge = length of the cut.

(2) *Example.* Determine the thickness and width of a ribbon charge for cutting a steel plate 1 inch thick.

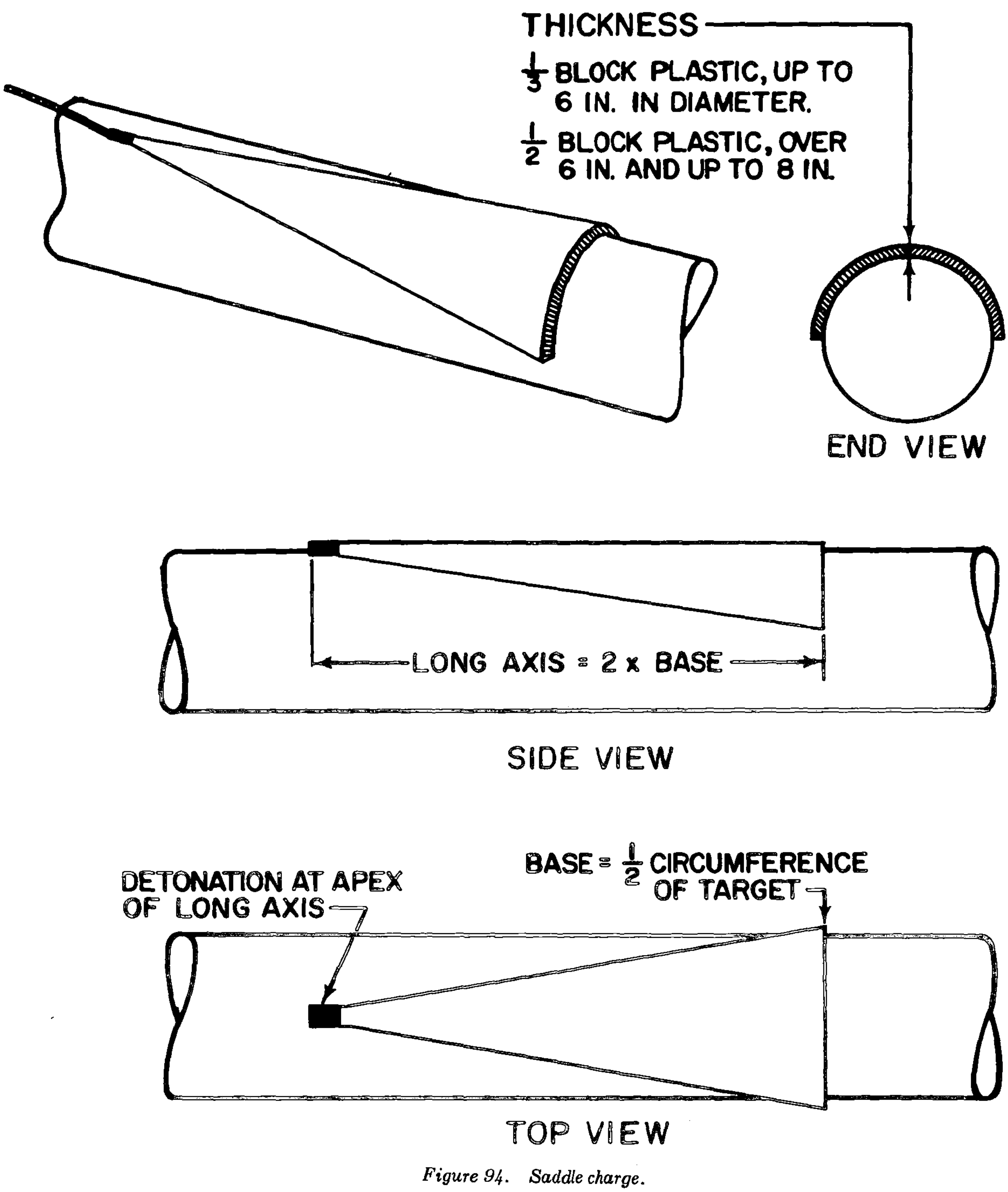


Figure 94. Saddle charge.

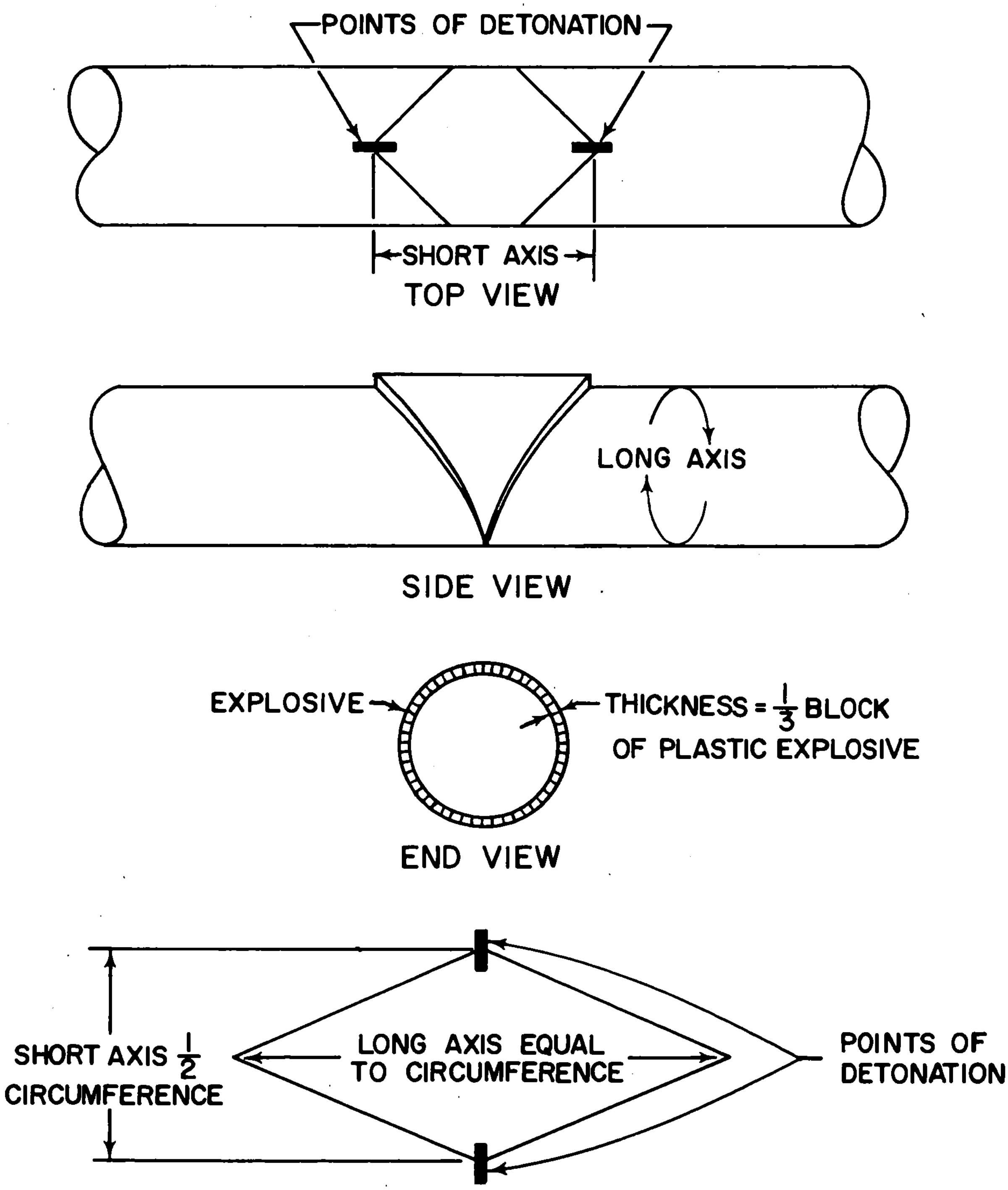


Figure 95. Diamond charge.

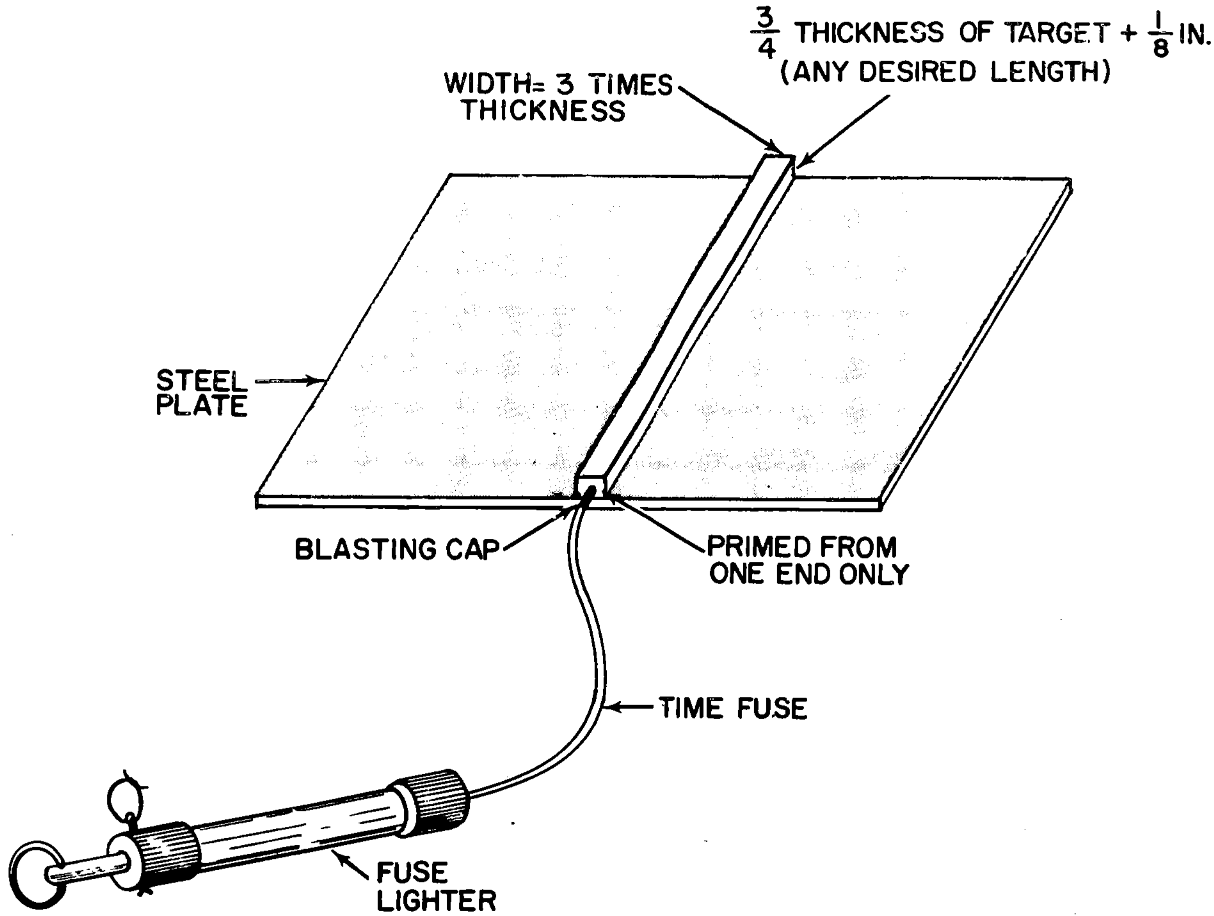
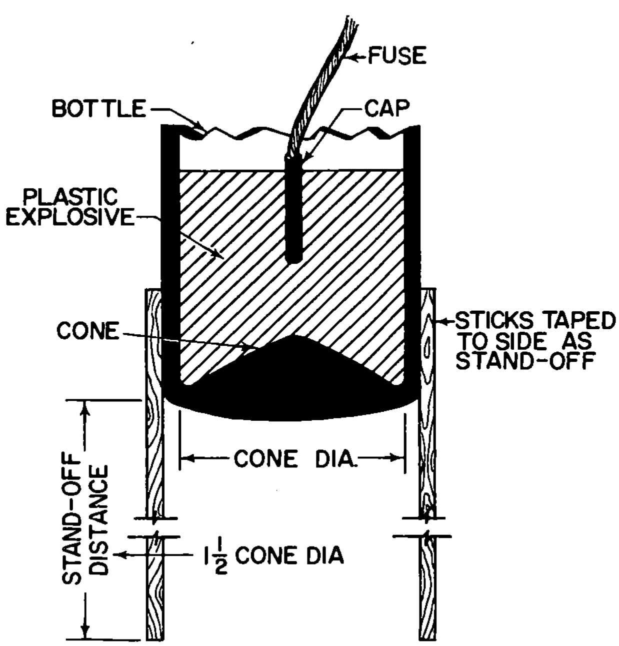


Figure 96. Ribbon charge.



ure 97. Shaped charge.

(*a*) Thickness = ½ × the thickness of material + ⅛ inch.
1 × ½ + ⅛ = ⅝ inches.

(*b*) Width – 2 × the thickness of the material.
2 × 1 = 2 inches.
Charge is ⅝ inches thick and 2 inches wide.

(3) *Placement.* The ribbon charge is detonated from one end only. It may be necessary, where the calculated thickness is small, to "build up" the detonating end with extra explosive. Either the electric or nonelectric cap is satisfactory. The steel member will be ruptured at approximately the center of the ribbon.

3. Shaped Charges

a. Description. Shaped charges concentrate the energy of the explosion released on a small area, making a tubular or linear fracture in the target. Their versatility and simplicity make them effective against many targets, especially those made of concrete or those with armor plating. Shaped charges are easily and readily improvised. Because of the many variables, such as explosive density, configuration, and density of the cavity liner, consistent results are impossible to obtain. Thus experiment, or trial and error, is necessary to determine the optimum standoff distance. Plastic explosive is best suited for this type of charge. Dynamite and molten TNT, however, may be used as an expedient.

b. Preparation. Almost any kind of container is usable (fig. 97). Bowls, funnels, cone-shaped glasses (champagne glasses with the stem removed), and copper, tin, cardboard, or zinc may be used as cavity liners. Bottles with a cavity in the bottom (champagne cognac bottles) are excellent. If none of these is available, a reduced effect is obtained by cutting a cavity into a plastic explosive block.

(1) Always detonate the charge from the exact top center.

(2) Make the angle of the cavity (cone) between 45° and 60° (most HEAT ammunition has 42° to 45° angle).

(3) Be sure the standoff distance is 1 to 1½ times the diameter of the cone.

(4) Be sure that the height of the explosive in the container is 2 times that of the cone, measured from the base to the top.

Note. The narrow necks of bottles or the stems of glasses may be cut by wrapping them with a piece of soft absorbent-type twine or string soaked in gasoline and lighting it. Two bands of adhesive tape, one on each side of the twine or string, will hold it firmly in place. The bottle or stem must be turned continuously, to heat the glass uniformly. Also a narrow band of plastic explosive placed around the neck and burned gives the same result. After the twine or plastic has burned, submerge the neck in water and break it off.

4. Counterforce ("Ear Muff") Charge

This technique is very effective against comparatively small concrete and masonry objects 4 feet or

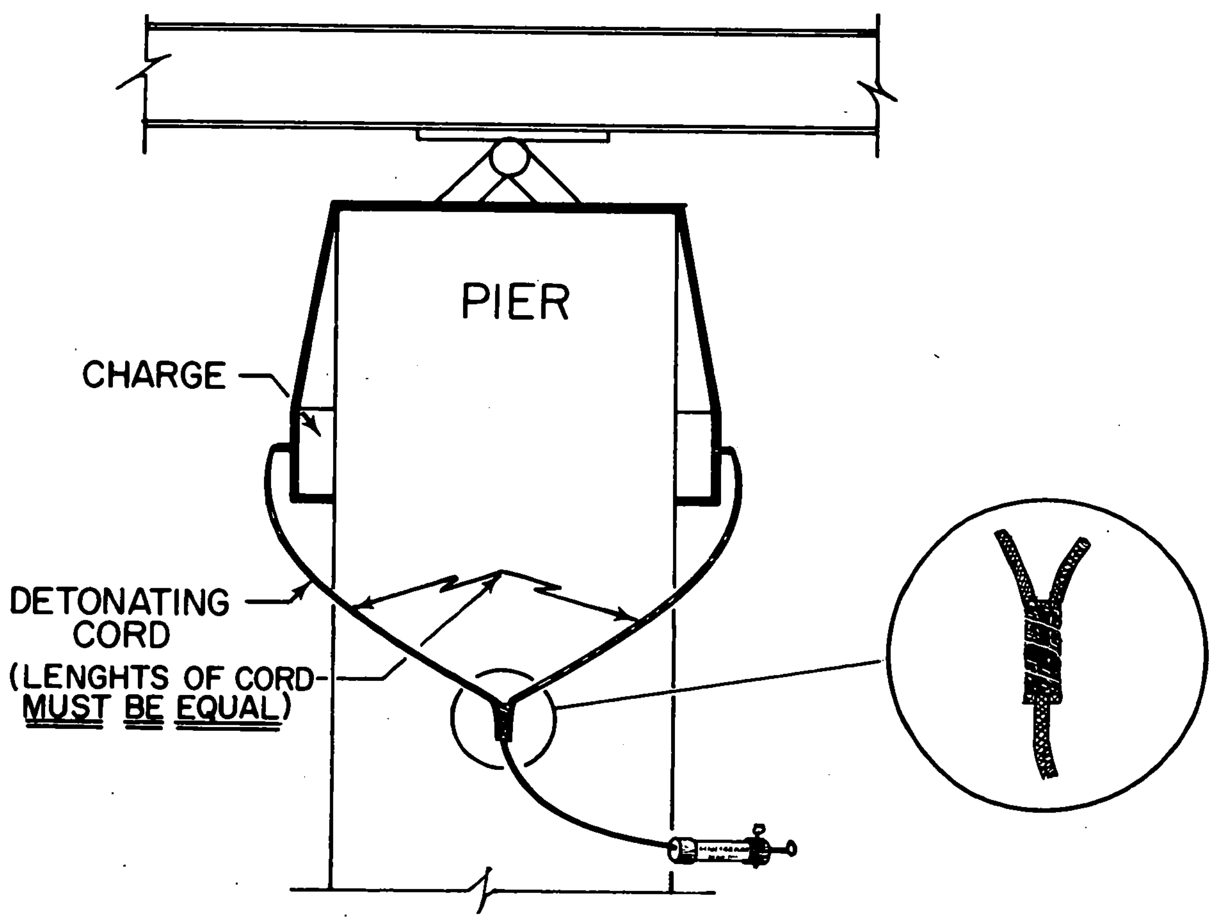


Figure 98. Ear muff charge.

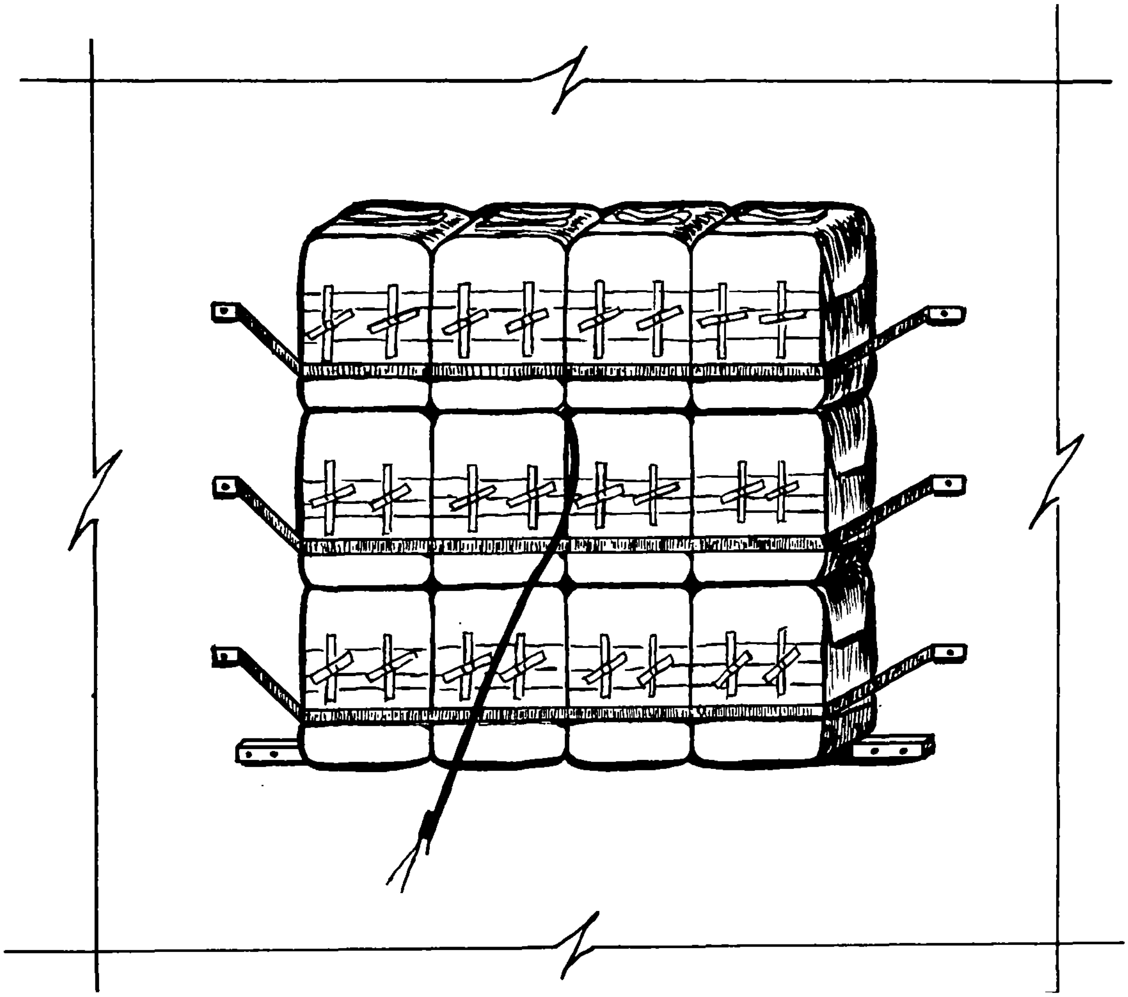


Figure 99. Square charge.

less in thickness, particularly cubical barriers and certain timber targets. If properly constructed, placed, and detonated, the counterforce charges produce excellent results with a relatively small amount of explosive. Their effectiveness results from the simultaneous detonation of two charges placed directly opposite each other and as near the center of the target as possible (fig. 98).

a. Charge Calculation. The size is computed from the diameter or thickness of the target in feet, as—

The amount of explosive = 2 × the thickness of the target.

Fractional measurements rounded off are to the next higher foot prior to multiplication. For example, a concrete target measuring 3 feet 9 inches thick requires 2 by 4 or 8 pounds of plastic explosive. This is relatively small in comparison with 124 pounds of TNT calculated by the standard formula for mid-air untamped placement.

b. Preparation and Emplacement. Divide the calculated amount of explosive in half to make two identical charges. The two charges *must* be placed diametrically opposite each other. This requires accessibility to both sides of the target so that the charges may be placed flush against the respective target sides. Two methods of providing critical placement are—

(1) *Rope.* Attach measured lengths of rope vertically and horizontally to both charges for center point positioning. This method is suited for targets with even dimensions, such as squares, and rectangles.

(2) *Frame.* This method is adaptable to use on concrete bridge piers. Construct a simple metallic or wooden frame, with the side or edge hinged, large enough to enclose the target. Unhinge one end or side of the frame and place it around the target.

Adjust the frame so that it will hold both charges in proper position, secure the open side or end, and level the frame. Temporary holding lines or stakes may be used to suspend the frame, if needed.

c. Priming. The simultaneous explosion of both charges is mandatory for optimum results. Crimp nonelectric blasting caps to *equal lengths* of detonating cord. Prime both charges at the *center rear point;* then form a V with the free ends of the detonating cord and attach an electric or nonelectric means of firing.

5. Square Charge

a. Description. This technique is applicable to the demolition of concrete and masonry bridge piers and other types of construction, but not steel. The charge for use on reinforced concrete walls up to 4 feet thick is composed of Composition C–4 blocks, 2 by 2 by 11 inches. They are placed as removed from the packing case. For walls from 5 up to 7 feet thick, the M–37 demolition kit may be used. It consists of 8 Composition C–4 blocks (20 lbs) assembled in a canvas haversack measuring approximately 4×8×11 inches (fig. 99). The blocks are not removed from the haversack, as it is easily fastened against the target. The size of the charge depends on the thickness of the target and the ratio of the thickness of the charge and the contact area. Although these charges, if square, are more effective than if rectangular, it is not always feasible to cut them to size. As most charges are rectangular, additional explosive is allowed for modifications in technique. The charges tabulated in *c* below, have proved effective.

b. Placement on Piers.

(1) Place the charge at least the thickness of the target above the base to obtain the maximum results. A small charge may be taped to the target or supported by a platform. Larger charges may be supported by strips of material and wire attached to the pier by fasteners driven into the concrete by means of the power-actuated driver.

(2) Initiate the charge from the center (fig. 99).

(3) Mud tamp the explosive on 1-foot thick targets, as this permits a 30-percent reduction in explosive weight.

c. Charge Size.

Concrete thickness	*Charge size*	*Charge thickness*
1 ft	2 C–4 blocks	One block—2 in.
2 ft	4 C–4 blocks	One block—2 in.
3 ft	7 C–4 blocks	One block—2 in.
4 ft	20 C–4 blocks	One block—2 in.
5 ft	6 M–37 kits (20 lb packet).	One kit—4 in.
6 ft	8 M–37 kits (20 lb packet).	One kit—4 in.
7 ft	12 M–37 kits (20 lb packet).	One kit—4 in.

6. Improvised Cratering Charge

This charge is a mixture of ammonium nitrate fertilizer containing at least 33⅓ percent nitrogen and diesel fuel, motor oil, or gasoline, at a ratio of 25 pounds of fertilizer to the gallon of liquid. The fertilizer must not be damp. From this mixture, improvised charges of almost any size or configuration can be made.

a. Mix the fertilizer and the diesel fuel, motor oil, or gasoline.

b. Allow the mixture to soak for an hour.

c. Place about half the charge in the borehole. Then place the primer, a primed 1-pound block of TNT, and add the remainder of the charge. Never leave the charge in the borehole for a long period, as accumulated moisture reduces its effectiveness.

d. Detonate the charge.

7. Relieved Face Cratering Method

This demolition technique produces a trapezoidal-shaped crater with unequal side slopes. The side nearest the enemy slopes at about 25° from the road surface to the bottom while that on the opposite or friendly side is about 30° to 40° steeper. The exact shape, however, depends on the type of soil found in the area of operations. In compact soil, such as clay, the relieved face cratering method will provide an obstacle shaped as shown in 1, figure 100. The procedure is as follows:

a. Drill two rows of boreholes 8 feet apart, spacing the boreholes on 7-foot centers. On any road, the row on the friendly side will contain four boreholes. Stagger the boreholes in the row on the enemy side, as shown in the sketch below. This row will usually contain three boreholes, or always one less than the other row (2, fig. 100).

b. Make the boreholes on the friendly side 5 feet deep and load with 40 pounds of explosive, and those on the enemy side 4 feet deep and load with 30 pounds of explosive.

c. Prime the charges in each row separately for simultaneous detonation. There should be a delay of detonation of ½ to 1½ seconds between rows, the row on the enemy side being detonated first. Best

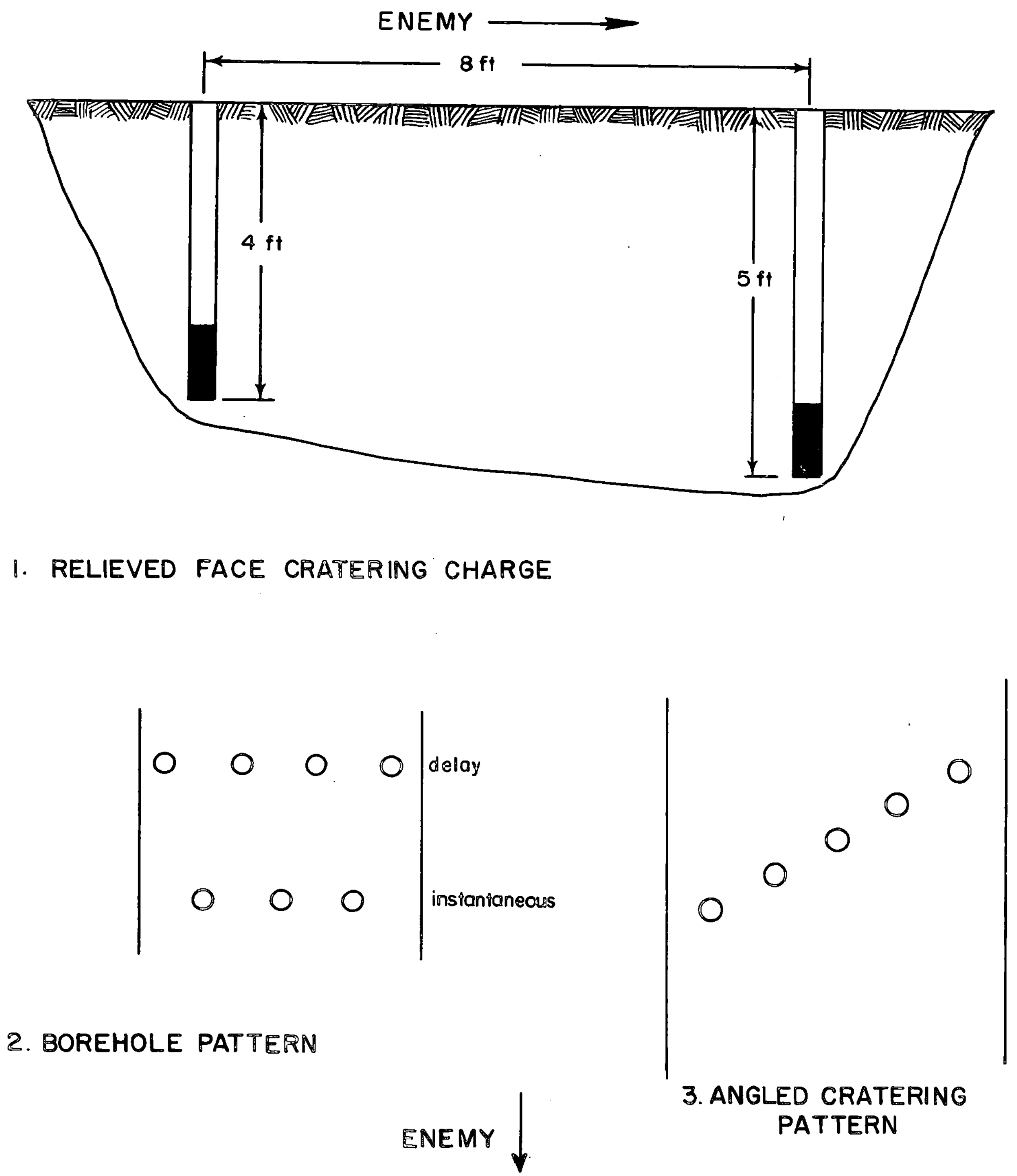


Figure 100. Cratering charge placement.

results will be obtained if the charges on the friendly side are fired while the earth moved in the first row is still in the air. Standard delay caps may be used for delay detonation.

d. If delay caps are not available, the necessary lapse may be obtained by the use of military electric or nonelectric blasting caps, as follows:

(1) *Nonelectric.* Connect the charges in each row with detonating cord and vary the time of detonation by priming the two rows with different lengths of time fuse.

(2) *Electric.* Connect each row of charges in a separate circuit and attach a blasting machine to each. The delay is thus manually controlled. If only one blasting machine is available, the desired delay may be obtained by firing one row and quickly connecting and firing the other. This should be easily accomplished in 1 to 2 seconds. As an alternative, the row on the enemy side may be primed nonelectrically and fired first, and the charge on the friendly side primed electrically and fired 1 or 2 seconds later by means of a blasting machine. This will also provide the proper delay.

e. Good results may be obtained by firing both rows simultaneously, if adequate means and sufficient time for delay firing are not available.

8. Angled Cratering Method

This method is useful against tanks traveling in defiles where they must approach the crater straightaway. A line of boreholes is blasted or drilled across a roadway and charged at about a 45° angle, as in 3, figure 100. Because of the unevenness of the side slope, tanks attempting to traverse an angled crater are usually halted effectively (fig. 100). The standoff distance for making the boreholes on unpaved roads with M2A3 shaped charges should be 20 to 30 inches. For paved roads, the standoff distance should be about 36 inches. As the standoff distance is decreased, the depth of the open hole is decreased, while the diameter is increased. In any case, test holes should be made to ascertain the optimum standoff distance.

Figure 101. Tank trapped in angled crater.

APPENDIX VII

USE OF EXPLOSIVES IN THE ARCTIC

1. Climatic Effects on Explosives and Their Preparation

The use of explosives under arctic conditions is complicated by low temperature effects on both explosives and crews. Explosives tend to detonate with reduced force, and personnel are handicapped by severe cold and bulky clothing.

2. Low Temperature Effects on Military Explosives

At low temperatures, military explosives lose some of their strength and steel-cutting effectiveness and become harder to initiate. Plastic explosive, on exposure to subzero temperatures, lose their plasticity; otherwise, their properties are generally the same as at moderate temperatures. Cold causes no breakdown of the explosive; and all types produce a high order detonation.

a. TNT. TNT is affected somewhat by intense cold, being less sensitive to shock.

b. Tetrytol. This explosive usually is not affected by cold except for a slight decrease in strength.

(1) *M1 chain demolition block.* The sensitivity of this explosive is decreased by cold like that of TNT. If blocks are separated by cutting, the ends of the detonating cord should be coated with waterproof grease to prevent penetration by moisture, which may cause a misfire.

(2) *M2 demolition block.* The M2 demolition block has slightly greater loss of strength at low temperatures than the M1. It requires six turns of the detonating cord instead of the usual four to obtain positive detonation. It retains its sensitivity to shock, however, as it ignites or explodes under .50-caliber incendiary machinegun fire at subzero temperatures.

c. M3 or M5 Demolition Block (C3). When chilled, C3 changes color from bright yellow to red, with no visible breakdown of material. Below −20° F., it becomes stiff and brittle; plasticity is restored only by reheating. Although at −20° F., the velocity is reduced, detonation is still of high order.

d. M5A1 Demolition Block (C4). C4 remains pliable like putty in temperatures between −70° F. and +170° F. Below −70° it becomes hard and brittle.

e. Shaped Charges. Shaped charges M2A3 and M3 are very useful for small arctic projects, especially for drilling holes, having the strength necessary to loosen permafrost and ice. Shaped charges, however, should not be used as a cure-all demolition explosive, as is the tendency; for the logistical difficulties of supplying them in large quantities generally limits their use.

f. Ammonium Nitrate. Except for the loss in strength characteristic at low temperatures, ammonium nitrate is satisfactory for use in the Arctic.

3. Low Temperature Effects on Commercial Dynamite

The sensitivity of dynamite decreases at diminishing temperatures until the dynamite freezes, after which it becomes extremely sensitive. Gelatin dynamite does not freeze as easily as straight dynamite. When straight dynamite is stored, the nitroglycerine tends to settle out of the sticks; accordingly, straight dynamite cases should be frequently and regularly turned until freezing sets in. Frozen dynamite may be thawed in a kettle as described in paragraph 148.

4. Low Temperature Effects on Demolition Accessories

a. Blasting Caps. Both electric and nonelectric blasting caps are unaffected by cold; and thus perform with equal reliability in arctic as in temperate climates. Despite their reliability, nonelectric caps are difficult to use and undesirable, as numerous manual operations are required, and time fuses fray when cut in cold weather. Moreover, extreme care is required to keep snow out of the caps during priming. Electric caps are easier than nonelectric caps to prepare. It is difficult, however, when wearing arctic mittens to splice wires by the "Western Union" or "pig tail" twists described in figure 32. A more satisfactory method is the "crank" tie, wherein the two ends of wire are placed side by side, the ends bent form a short crank, and the wires wound together by turning crank. This makes a quick, taut connection, which becomes tighter by pulling. All the enamel should be removed from the bare wires before making the crank tie.

b. Detonating Cord. The detonating cord does not lose its explosive properties by exposure to long periods of cold. Even during severe drops in temperature, it fires all standard military explosives. The only variation in method is the use of six instead of the normal four turns when detonating the M2 (tetrytol) demolition block. On the other hand the outer covering of chilled detonating cord becomes stiff and cracks when bent. Repeated flexings deepen the cracks and break the explosive train. Care must be taken to insure a minimum of cranking in tying detonating cord; and connections must be checked for tightness, as the cord tends to loosen after being tied (par. 50).

c. Time Fuse. Although the powder train of the time fuse does not break down or deteriorate during long periods of cold, the outside covering becomes brittle and cracks easily. It is thus necessary to handle time fuse carefully during priming to prevent this cracking and breaking the powder train. The burning rate is determined in the same manner as when it is used in a moderate climate—a measured length is cut off and burned in the area and at the temperature in which it will be used (par. 29). A good procedure is to cut time fuse in a warm shelter and keep it next to the body until time for priming. Nonelectric firing, however, is undesirable in arctic-subarctic temperatures.

d. Fuse Lighters.

(1) *M2.* The M2 weatherproof fuse lighter is unsatisfactory for arctic use, as the percentage of failures is too high. The warming of the lighter and fuse, just before using them, reduces failures to a marked degree. Because of the tendency of the fuse end to fray, repeated cuts may have to be made before it can be inserted deeply enough into the M2 lighter to be ignited.

(2) *M60.* The M60 fuse lighter has been tested under extreme cold conditions and found satisfactory. It functions without failure at temperatures as low as −25° F.

e. Delay Detonator. The 15-second delay detonator consists of a pull type fuse lighter, a length of time fuse, and a blasting cap, inclosed in a waterproof cylinder that is threaded to fit a standard cap well. The 15-second delay detonator performs satisfactorily in the Arctic. The cold does not affect adversely the mechanical function of the detonator or of its components. Although low temperatures do cause an abnormally long delay, the detonator always ignites the charge. At −20° F., the average delay is increased by 2 to 4 seconds.

f. Blasting Machines. Both the 10-cap and 30-cap blasting machines fire satisfactorily their rated number of electric caps after prolonged exposure to arctic conditions. Although low temperatures retard the mechanical operation of the armature, normal rotation may be obtained by vigorous operation of the handle at least ten times before firing. The handle on the 10-cap blasting machine is inclined to break at the connecting slot, especially after prolonged chilling. Thus the device should be carefully loosened before operation. The lead wires are difficult to attach by operators wearing heavy mittens.

g. Galvanometers. The standard silver chloride dry cell installed in all galvanometers is unsatisfactory in demolitions in the arctic, as it freezes and ruptures, completely ceasing operation at temperatures below 0° F. If, however, the galvanometer is warmed by heating and then placed next to the body until use, it gives a partial scale reading that is usable.

h. Other Equipment. All equipment in demolition sets 1, 2, 5, and 7, not discussed in *a* through *g* above, perform satisfactorily under arctic winter conditions except the items below—

(1) *Cap sealing compound.* Because of its high viscosity and the difficulty of thawing and keeping it warm, cap-sealing compound is unsatisfactory for use in the Arctic.

(2) *Engineer pocket knife.* The engineer pocket knife is not sturdy enough for arctic use. The blades do not hold their sharp edges at subzero temperatures.

(3) *Firing wire and reel.* This equipment must be kept free of ice and snow. All snow must be removed during rewinding.

5. Blasting Permafrost

a. Number of Boreholes and Size of Charge. In permafrost, blasting requires about 1½ to 2 times the number of boreholes and larger charges than those calculated by standard formulas for moderate climates. Frozen soil, when blasted, breaks into large clods 12 to 18 inches thick and 6 to 8 feet in diameter. As the charge has insufficient force to blow these clods clear of the hole, they fall back into it when the blast subsides. Tests to determine the number of boreholes needed should be made before extensive blasting is attempted. In some cases permafrost may be as difficult to blast as solid rock.

b. Methods of Making Boreholes. Boreholes are made by three methods—standard drilling equipment, steam point drilling equipment, and shaped charges. Standard drill equipment has one serious defect—the air holes in the drill bits freeze; and there is no known method of avoiding it. Steam point drilling is satisfactory in sand, silt, or clay, but not in gravel; charges must be placed immediately upon withdrawal of the steam point, otherwise the area around the hole thaws and plugs it. Shaped charges also are satisfactory for producing boreholes, expecially for cratering. Table IX shows the size of boreholes in permafrost and ice made by M3 and M2A3 shaped charges.

c. Explosives. A low velocity cold weather explosive should be used, if available. The heaving quality of low velocity explosives will aid in clearing the hole of large boulders. If only high velocity explosives are available, charges should be tamped with water and permitted to freeze. Unless high velocity explosives are thoroughly tamped, they tend to blow out the borehole.

6. The Blasting of Ice

a. Access Holes. These are required for water supply and determining the thickness of ice for the computation of safe bearing pressures for aircraft and vehicles. As ice carries much winter traffic, its bearing capacity must be ascertained rapidly when forward movements are required. Small diameter access holes are made by shaped charges. On solid lake ice, the M2A3 penetrates 7 feet and the M3, 12 feet (table IX). These charges will penetrate farther but the penetration distances were tested only in ice approximately 12 feet thick. If the regular standoff is used, a large crater forms at the top, which makes considerable probing necessary to find the borehole. If a standoff of 42 inches or more is used with the M2A3 shaped charge, a clean hole without a top crater is formed. Holes made by the M2A3 average 3½ inches in diameter, while those made by the M3 average 6 inches.

b. Ice Conditions. In the late winter after the ice has aged, it grows weaker and changes color from blue to white. As the structure of ice varies and its strength depends on age, air temperature, and conditions of the original formation, the proper shaped charge standoff distances in all cases is hard to calculate. In fact, the same size and type of crater is formed regardless of the standoff distance. If the lake or river is not frozen to the bottom and there is a foot or more of water under the ice, the water will rise to within 6 inches of the top after the hole is blown, carrying shattered ice particles with it. This makes the hole easy to clean. If the lake is frozen to the bottom, the blown hole will fill with shattered ice, and clearing will be extremely difficult. Under unusual ice conditions shaped charges may penetrate to a depth much less than that indicated in table IX.

c. Surface Charges. Surface craters may be made with ammonium nitrate cratering charges or TNT, M1, M2, or M3 demolition blocks. For the best effects, the charges are placed on the surface of cleared ice and tamped on top with snow. The tendency of ice to shatter more readily than soil should be considered when charges are computed.

d. Underwater Charges.

(1) Charges are placed underwater by first making boreholes in the ice with shaped charges, and then placing the charge below the ice. An 80-pound charge of M3 demolition blocks under 4½ feet of ice forms a crater 40 feet in diameter. This crater, however, is filled with floating ice particles, and which, at temperatures around −20° F., freezes over in 40 minutes.

(2) A vehicle obstacle may be cratered in ice by sinking boreholes 9 feet apart in staggered rows. Charges (tetrytol or C3) are suspended about 2 feet below the bottom of the ice by means of cords with sticks bridging the tops of the holes. The size of the charge depends upon the thickness of the ice. Only two or three charges are primed—one at each end and one at the middle. The others will detonate sympathetically. Making an obstacle like this will retard or halt enemy vehicles for approximately 24 hours at temperatures around −24° F.

7. Timber-Cutting Charges

Arctic temperatures have little visible effect on timber cutting. Composition C4 explosive is used. The size of the charge is computed as described in paragraph 71.

8. Steel-Cutting Charges

Satisfactory steel-cutting charges are calculated by the formulas in paragraph 76*b*. M3 shaped charges laid against 24-inch laminated armor plate penetrate 17¾ inches at −40° F. Composition C4, however, is the most effective explosion for cutting steel because of its molding characteristics, which remain satisfactory even at extreme temperatures. Composition C3 is equally effective down to about −15° F., but loses its plasticity as it approaches −20° F. Hard, block type explosives may be used, but they require overcharging as they cannot be molded into the bends and corners of structural steel members.

9. Pressure and Breaching Charges

Satisfactory results may be obtained for breaching and pressure charge work by calculating the size of the charge according to formula (pars. 81 and 86). Low temperatures do not appreciably modify the effectiveness of such charges.

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