FM 5-25

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
INTRODUCTION

Section I. GENERAL

1. Purpose

This manual provides information and guidance for all personnel engaged in training for, or conducting, demolition operations.

2. Scope

This manual discusses the types, characteristics, usage, handling, storage, transportation, and safety precautions of explosives and demolitions equipment. The preparation, calculation, placement and firing of charges, along with appropriate formulas, are described and illustrated. Deliberate and hasty demolition procedures suitable for use in the forward combat zone are outlined. The material presented herein is applicable to both nuclear and nonnuclear warfare.

Section II. PRINCIPLES OF EXPLOSIVES

3. Definitions

a. Explosive. Substance which, when subjected to heat, impact, friction, or other suitable initial impulse, undergoes a very rapid chemical transformation, forming other more stable products entirely or largely gaseous, whose combined volume is much greater than that of the original substance.

b. Demolitions, Military. The destruction by explosives, fire, water, mechanical or other means, of structures or materials as a matter of military necessity or expediency.

4. Classification of Explosives

Explosives are classified as low explosives or high explosives according to the speed (expressed in feet per second) at which the change of state takes place.

a. Low Explosives. Low explosives, such as black powder and smokeless powder, change from a solid to a gaseous state relatively slowly. The reaction causing this change is called deflagration. A deflagrating explosive is one that burns progressively over a relatively sustained period of time, and this action can be utilized to push or shove, rather than to rend and tear, the object against which it is placed. The principal military use of the low explosive is as the propelling charge for a projectile and for powder trains such as in a time fuze.

b. High Explosives. High explosives, such as TNT and dynamite, change from a solid to a gaseous state almost instantaneously. The reaction causing this change is called detonation. A high explosive is detonated by heat or by shock, which sets up a detonating wave. This wave passes through the entire mass of the explosive almost instantaneously, changing the explosive from a solid to a gaseous state. The sudden generation of gases and their extremely rapid expansion produces a shattering effect which can overcome great resistance in their path. The velocity of detonation of an explosive is the rate, in feet per second, at which the detonating wave travels through a column of the explosive. The principal military uses of high explosives are to execute all types of engineer demolitions, and to provide the charges in high explosive shells and bombs. Principal types of high explosives for military purposes are included in table I.

5. Desired Properties of Military Explosives

The desirable properties of military explosives are as follows:

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

b. Proper detonating velocity for intended purposes.

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 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.

6. Principal Military Explosives

The principal types of explosives commonly used for military purposes are shown in table I. The table indicates the principal uses of these explosives; however, they may be used for other purposes when necessary. In using the table to determine the proper type of explosive to be employed for a specific purpose the velocity of detonation should be considered. Explosives with a high velocity of detonation are generally used for cutting and breaching, while those with a lower velocity of detonation are used for cratering, ditching, and quarrying.

Table I. Characteristics of Principal United States 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, general and military use in forward areas.	Special blasting cap, electric or nonelectric.	21, 000	1. 00	Dangerous	Excellent
Tetrytol			23, 000	1. 20	Dangerous	Excellent
Composition C–3			26, 000	1. 34	Dangerous	Good
Composition C–4			26, 000	1. 34	Slight	Excellent
Ammonium Nitrate	Cratering and ditching		11, 000	0. 42	Dangerous	Poor
Military Dynamite M1	Quarry and rock cuts		20, 000	0. 92	Dangerous	Good
Straight Dynamite (commercial) 40%	Land clearing, cratering, quarrying, and general use in rear areas.	No. 6 commercial cap, electric or nonelectric.	15, 000	0. 65	Dangerous	Good (if fired within 24 hrs).
50%			18, 000	0. 79		
60%			19, 000	0. 83		
Ammonia Dynamite (commercial) 40%			9, 000	0. 41	Dangerous	Poor
50%			11, 000	0. 46		
60%			12, 000	0. 53		
Gelatin Dynamite 40%			8, 000	0. 42	Slight	Good
50%			9, 000	0. 47		
60%			16, 000	0. 76		

Table I—Continued

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
PETN	Detonating cord	Spec. blasting cap*	24, 000	1. 66	Slight	Good
	Blasting Caps	N/A				
TETRYL	Booster Charge	Spec. blasting cap*	23, 400	1. 25	Dangerous	Excellent
	Blasting Caps	N/A				
Composition B	Bangalore Torpedo	Spec. blasting cap, electric or nonelectric.	25, 500	1. 35	Dangerous	Excellent
Amatol 80/20	Bangalore Torpedo		16, 000	1. 17	Dangerous	Poor
Black Powder	Time blasting fuze	N/A	(unknown)	0. 55	Dangerous	Poor

*Electric or nonelectric.

CHAPTER 2

MILITARY EXPLOSIVES

Section I. DEMOLITION BLOCKS AND CRATERING CHARGES

7. TNT (Trinitrotoluene)

a. General. Trinitrotoluene (fig. 1), commonly known by the abbreviation TNT, is one of the least sensitive of military high explosives. TNT is reasonably stable in any climate, is not affected by moisture, and is one of the most durable of military explosives for underwater use.

b. Packaging. TNT, which is catalogued as "explosive TNT," is

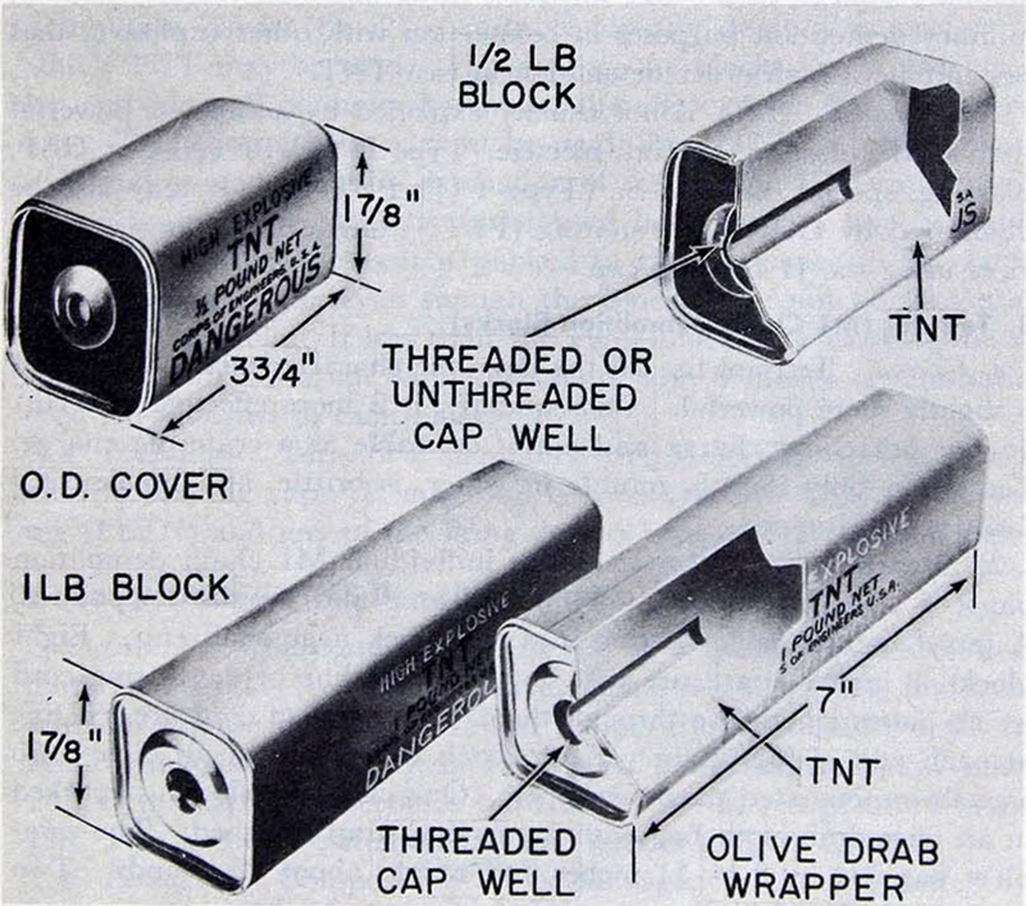


Figure 1. TNT Blocks.

packaged in ½-pound blocks, 1-pound blocks, and 8-pound blocks as follows:

(1) The ½-pound blocks are contained in an olive drab wrapper with metal ends. One end is provided with a threaded or unthreaded cap well to receive an electric or nonelectric blasting cap. The ½-pound blocks are packed 100 in a rectangular wooden box.

(2) The 1-pound blocks each consist of two otherwise unwrapped ½-pound blocks of TNT in an olive drab wrapper with metal ends. One end is provided with a threaded cap well to receive an electric or nonelectric blasting cap. Priming adapters and the standard base on firing devices fit these threads on the cap wells. Fifty 1-pound blocks are packed in a wooden box.

(3) The 8-pound block is made of cast TNT and is individually wrapped in a waterproof barrier material, properly sealed. Eight of these blocks are packed in a wooden box.

c. Uses. TNT is extensively employed for general military use in forward combat areas. The ½- and 1-pound blocks are used primarily for cutting and breaching projects. The 8-pound block is used as an auxiliary charge to the M6 antitank mine and also for any suitable military demolition purposes in connection with other explosives that can initiate a high order detonation in cast TNT.

d. Detonation. TNT is not usually exploded by a cap less powerful than CAP, blasting, special, electric (Type II (J2 PETN)), or CAP, blasting, special, nonelectric (Type I (J1 PETN)). It may also be detonated by CORD, detonating (PETN) and any of the firing devices using the J1 blasting cap.

8. Tetrytol (M1 Chain Demolition Blocks)

a. General. Tetrytol has all the desirable characteristics of TNT and is slightly more powerful. Consequently, it is more effective as a cutting or breaching charge and is not desirable as a cratering charge. Tetrytol is only slightly soluble in water, is brittle, and breaks very easily when dropped.

b. Description and Packaging. The individual M1 chain demolition block is 2 inches square by 11 inches long and weighs 2½ pounds. A tetryl booster pellet is cast into the block near each end. Eight blocks, 8 inches apart, are cast onto a single line of detonating cord which passes lengthwise through them. Two feet of cord are 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 bag with a carrying strap attached. The complete bag is 4 by 8 by 11 inches and weighs about 22 pounds. Two complete bags, 16 blocks, are packed in a wooden box.

c. Uses of M1 Demolition Blocks. Tetrytol, in the form of M1 chain

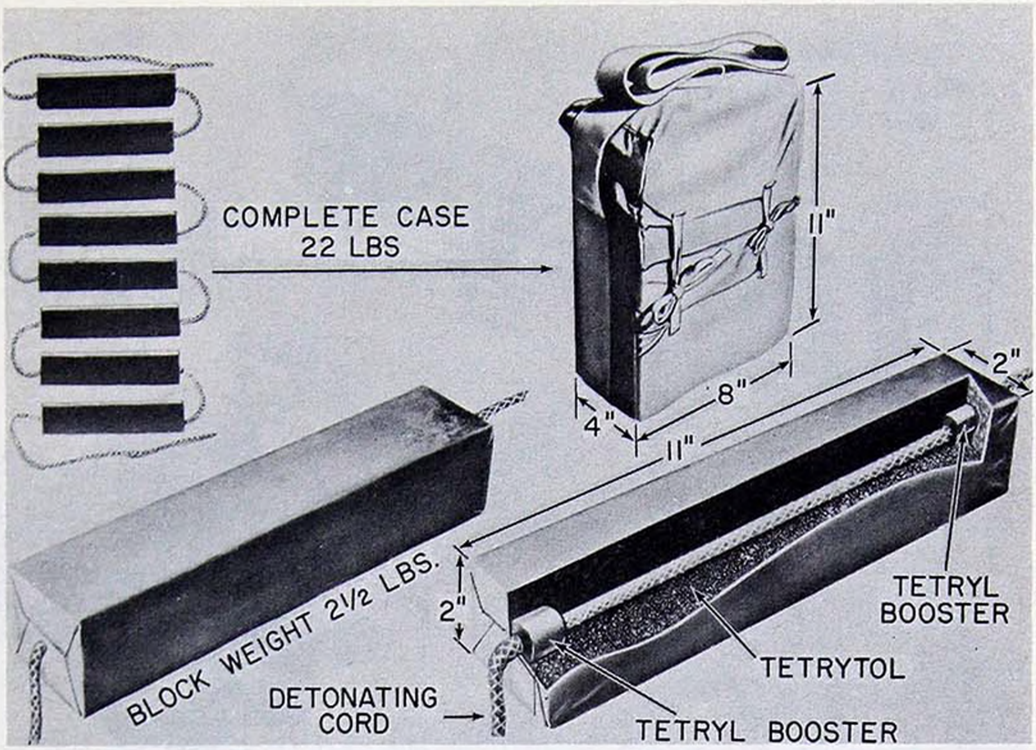


Figure 2. M1 chain demolition blocks.

demolition blocks (fig. 2) is suitable for any demolition project for which TNT may be used. However, if the blocks are broken up to be used in small diameter boreholes, the effect of the tetryl booster is lost. Therefore, a booster must be made from TNT or plastic explosives and primed to insure detonation of the charge. The entire chain, or any part of the chain, may be used laid out in a line, wrapped around an object, or as it is packed in the haversack. The entire chain will detonate, even though the blocks may not be in contact with one another. If less than the eight blocks are needed, the required number are cut from the chain with 8 inches of detonating cord left attached to each block.

d. Detonation. Tetrytol is detonated by the special electric or nonelectric blasting cap. It may also be detonated by CORD, detonating (PETN) and any of the firing devices using the J1 blasting cap.

9. Composition C3 (M5 Demolition Block)

a. General. Composition C3 (fig. 3) is a plastic explosive more powerful than TNT. This explosive catches fire very easily and burns with an intense heat. In normal temperature composition C3 has about the same sensitivity as TNT. At temperatures below minus 20° F. the explosive becomes hard or brittle; at temperatures above 120° F. it becomes extremely soft and exudes some of its oils.

b. Packaging. Composition C3 is packaged as the M5 demolition block. It is not packaged in bulk form, but the M5 demolition block

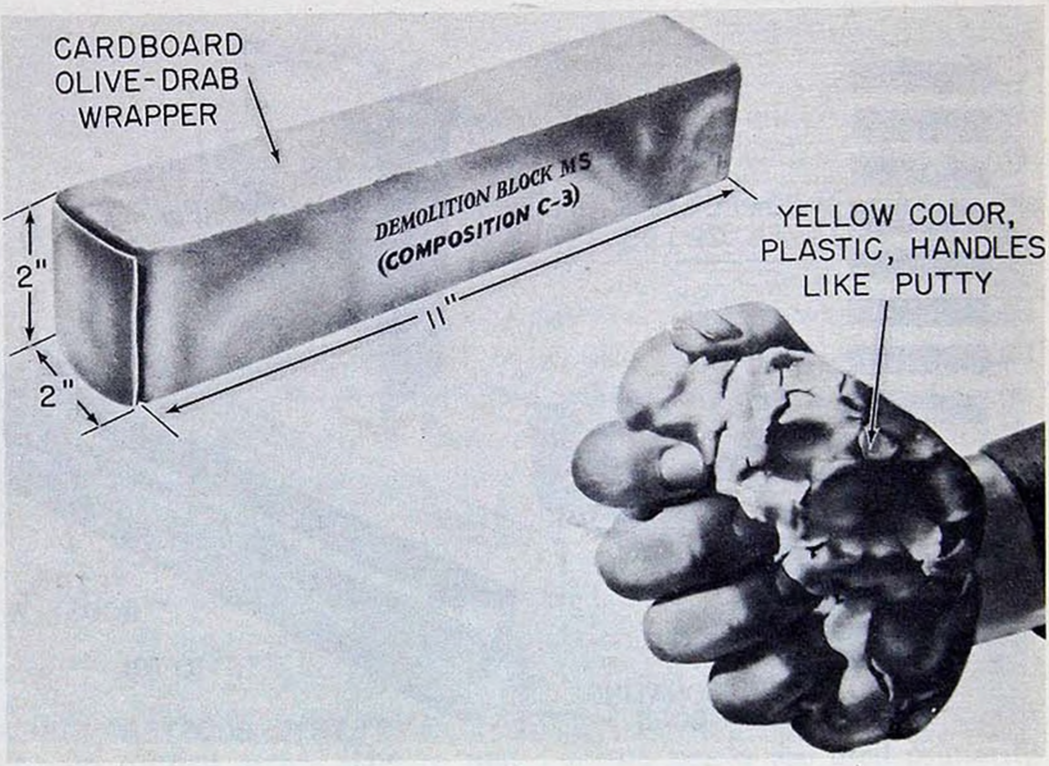


Figure 3. M5 demolition block.

is perforated around the middle to facilitate breaking it open. Bulk Composition C3 is procured in this manner whenever needed. Each M5 demolition block measures 2 inches square by 11 inches long, and weighs 2¼ pounds. Each block is wrapped in glazed paper and inclosed in a labeled olive-drab cardboard container. Eight M5 demolition blocks are packed in a haversack, and two of these filled haversacks are packed in a wooden box.

c. Uses. Composition C3, because of its high velocity of detonation and its plasticity, is ideally suited for cutting steel. Its plasticity permits it to be molded in close contact to irregularly shaped objects for demolition purposes. This explosive may be used as an underwater charge if it is inclosed in a suitable container to prevent erosion.

d. Detonation. Composition C3 may be detonated with the special blasting cap, either electric or nonelectric. It may also be primed with detonating cord. The various detonators may also be used.

10. Composition C4 (M5A1 Demolition Block)

a. General. Composition C4 (fig. 4) is a white plastic explosive, more powerful than TNT, does not have the offensive odor, and will not stain the hands as does C3. It is plastic over a wide range of temperatures and has about the same sensitivity as TNT. Composition C4 possesses many advantages over C3.

(1) Composition C4 is more stable.

(2) Composition C4 is less sticky and will not adhere to the hands as much as Composition C3.

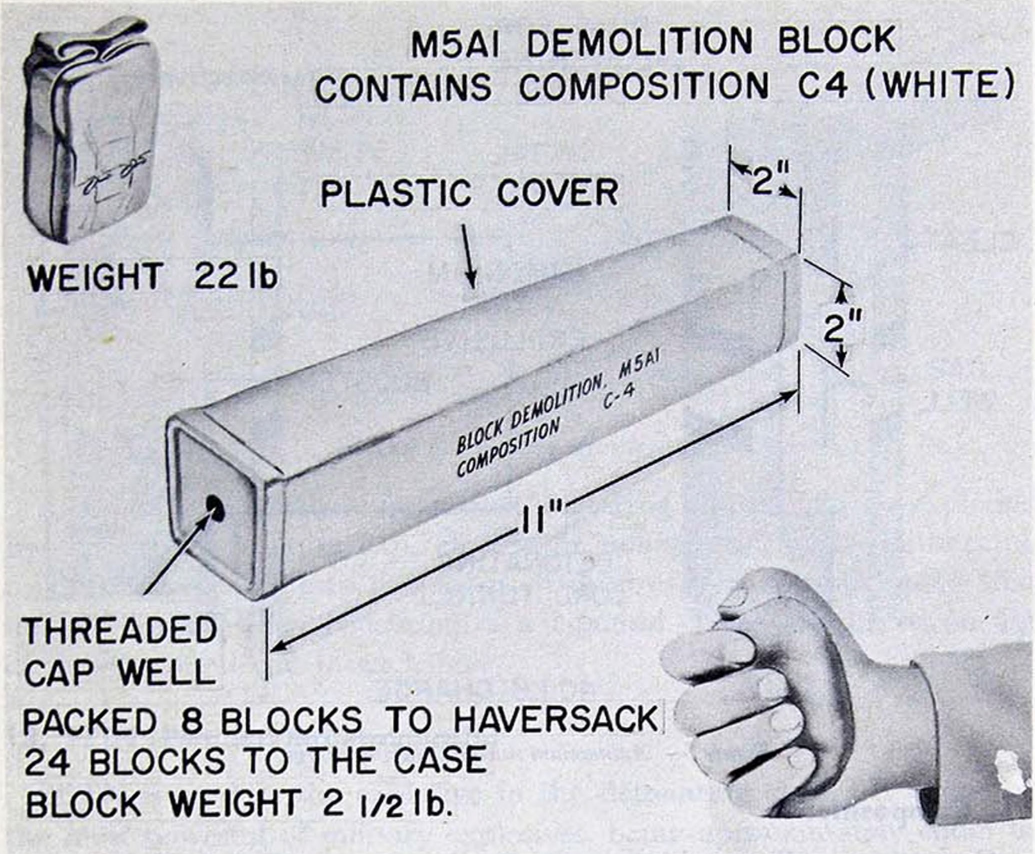


Figure 4. M5A1 demolition block.

(3) Composition C4 is less subject to erosion than Composition C3 when used as an underwater charge and subjected to immersion for long periods.

b. Packaging. Composition C4 is packaged as M5A1 demolition blocks. Each block measures 2 inches square by 11 inches long, and weighs 2½ pounds. Each block is wrapped in a plastic covering with a threaded cap well at one end for use as a block explosive. Eight blocks are placed in a haversack and two of these filled haversacks are packed in a wooden box. Bulk Composition C4, like bulk Composition C3, must be obtained by breaking open the demolition blocks containing the explosive.

c. Uses. Composition C4, because of its high velocity of detonation and its plasticity, is ideally suited for cutting steel, timber, and breaching concrete. Its plasticity permits close contact for the demolition of irregularly shaped objects. This explosive may be used as an underwater charge if it is inclosed in a suitable container to prevent erosion by stream current.

d. Detonation. . Composition C4 may be detonated with the special blasting cap, either electric or nonelectric. It may also be detonated by CORD, detonating (PETN) and any of the firing devices using the J1 blasting cap.

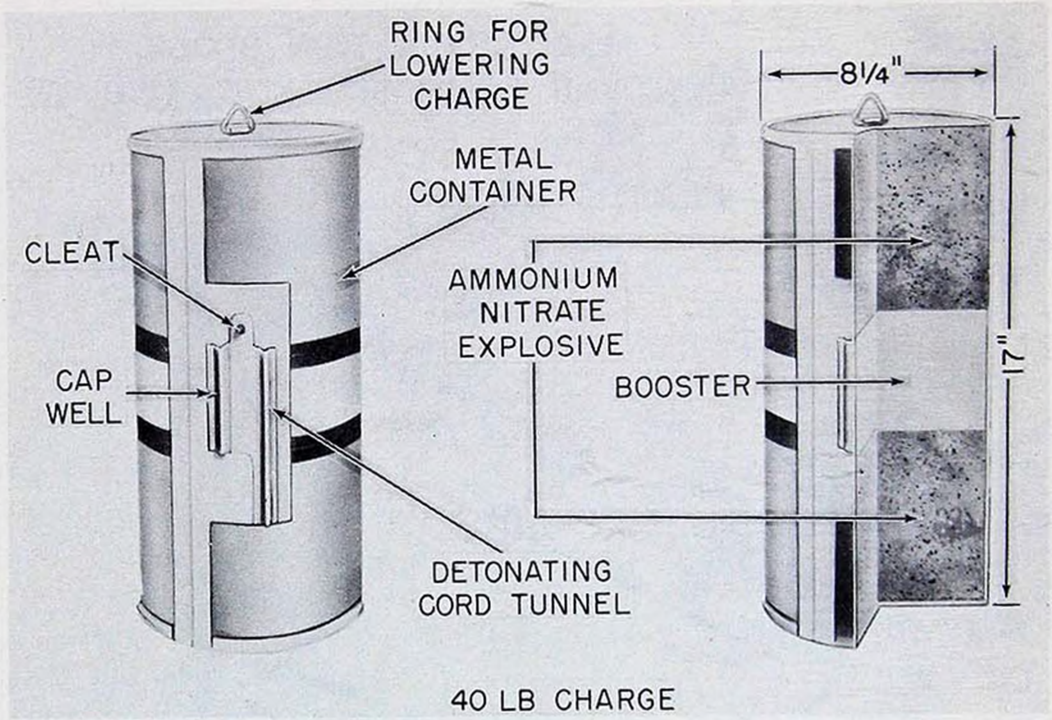


Figure 5. Ammonium nitrate cratering charge.

11. Composition B

Composition B is a high explosive having a relative effectiveness higher than that of TNT, but is more sensitive than TNT. Because of its shattering power and high rate of detonation Composition B is now being used as the main charge in the bangalore torpedo.

12. Ammonium Nitrate

a. General. Ammonium nitrate (fig. 5) is the least sensitive of any of the military explosives. This explosive is only half as powerful as TNT and because of a low velocity of detonation its shattering power is relatively low. It absorbs moisture readily, which rapidly reduces its efficiency to a point where it is useless. It should be protected at all times from exposure to the air by being kept in the metal container.

b. Packaging. Ammonium nitrate cratering explosive is issued as a 40-pound charge packed in a watertight, cylindrical, metal container, 8¼ inches in diameter by 17 inches high. A cap well and a detonating cord tunnel are attached to the container to accommodate the primer. To insure detonation, a booster is provided within the charge. A metal ring is provided on top of the container for lowering the charge into a hole. The cleat above and to the side of the cap well is used when the charge is primed either nonelectrically or electrically.

c. Uses. Ammonium nitrate is used primarily as a cratering charge because its slow velocity of detonation results in the desired pushing or heaving effect. This explosive can also be used in ditching and quarry operations.

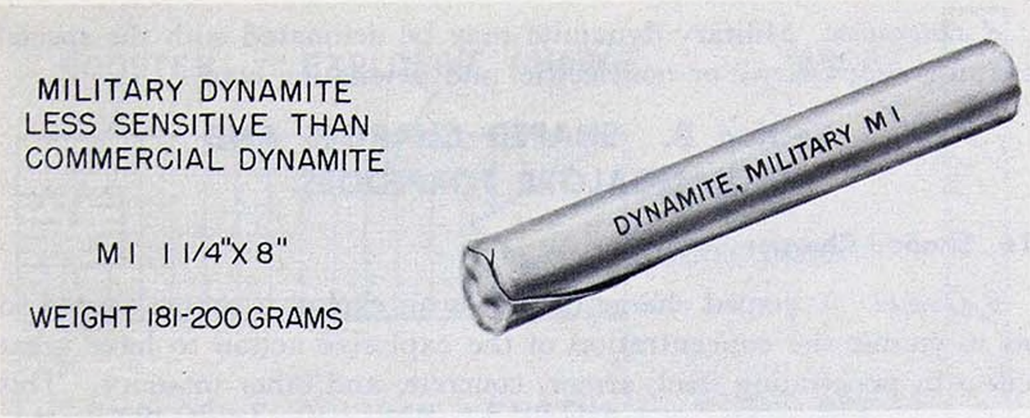


Figure 6. Military dynamite.

d. Detonation. Ammonium nitrate cratering charge can be exploded by the special blasting cap, electric or nonelectric, or by detonating cord. However, due to frequency of misfires it is recommended that an additional primer consisting of a 1-pound charge be placed on top of the 40-pound can in each hole.

13. PETN (Pentaerythritetranitrate)

PETN is used as the explosive in the detonating cord. It is one of the most powerful of military explosives, being approximately equal to nitroglycerin. PETN, although possessing the high velocity of detonation of 21,000 feet per second, is relatively insensitive to friction and ordinary shock.

14. Amatol

Amatol is a high explosive consisting of a mixture of ammonium nitrate and TNT. Its relative effectiveness is slightly higher than that of TNT. The 80/20 amatol was formely used as the explosive content of the bangalore torpedo, but is being replaced by Composition B.

15. Military Dynamites

a. General. Military dynamite was developed to give field troops an explosive for quarry blasting that meets military requirements. The composition, unlike commercial dynamite, is odorless, does not absorb or retain moisture, and contains no nitroglycerin. Thus safety in storage, handling, and transportation is greater than for commercial dynamite.

b. Packaging. The composition is packaged in standard dynamite cartridge waxed paper wrappers.

c. Uses. Military dynamite (M1), is a stick 1¼ x 8 inches and weighs 181–200 grams. Its velocity of detonation is approximately 20,000 ft./sec. Its great heaving force makes it ideal for military construction, quarrying and other service demolition work.

d. Detonation. Military dynamite may be detonated with the special blasting cap, electric or nonelectric, and detonating cord.

Section II. SHAPED CHARGES AND BANGALORE TORPEDOES

16. Shaped Charges

a. General. A shaped charge (fig. 7) is an explosive charge shaped so as to enable the concentration of the explosive action to have great effect in penetrating steel, armor, concrete, and other masonry. This is known as the "Monroe effect." As used, a shaped charge consists of the essential parts shown in figure 8. Shaped charges are cylindrical and have a conical top and a conical recess in the base. The cone liner may be of metal, glass, or other inert material. A threaded cap well in the top accommodates any standard firing device. Most commonly used explosives are Composition B, pentolite, and ednatol.

b. M2A3 Shaped Charge. The M2A3 (fig. 7) shaped charge weighs 15 pounds and contains 11½ pounds of pentolite (PETN and TNT) or Composition B (RDX and TNT) in a water-resistant fiber container. The conical top of this charge is slightly larger in diameter than the top of the old M2 shaped charge. The cardboard cylinder, assembled to the charge before use, provides necessary standoff distance. Three

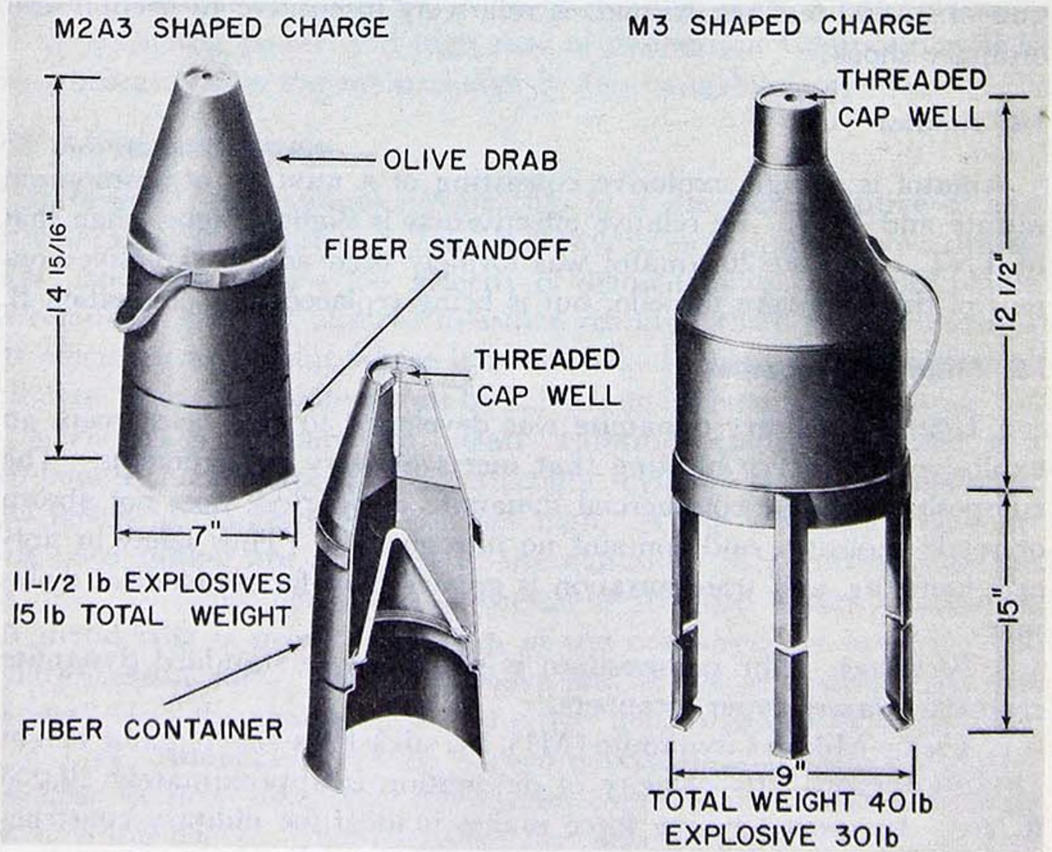


Figure 7. Shaped charges.

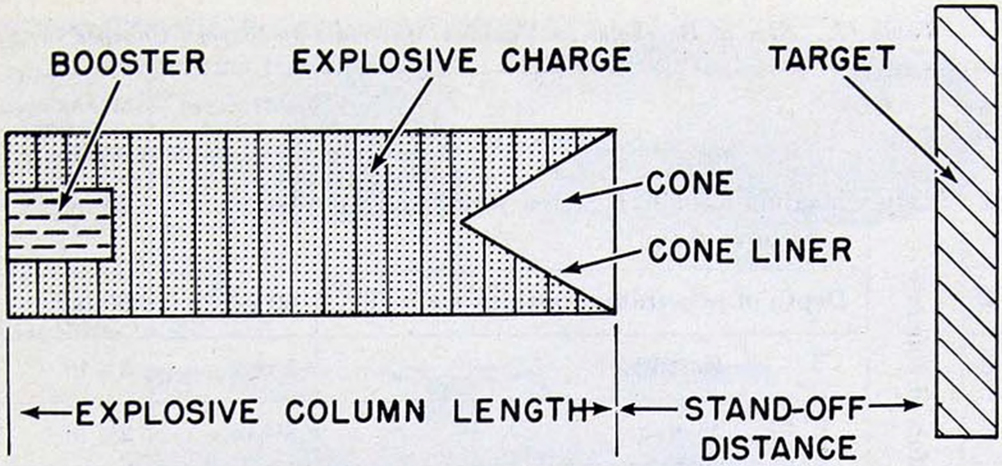


Figure 8. Essential parts of shaped charges.

M2A3 shaped charges are packed in a wooden box. The gross weight of each box of charges is approximately 50 pounds.

c. M3 Shaped Charge. This charge (fig. 7) contains approximately 30 pounds of 50/50 pentolite, or Composition B with a 50/50 pentolite booster, in a metal container. The cavity liner is made of metal. The correct standoff distance is provided for by a metal tripod. The shaped charge M3 is packed one per fiber container, one container per wooden box.

d. Effects of Shaped Charges. The effectiveness of a shaped charge is largely governed by the explosive that is used. The shaped charge should always be placed a specified standoff distance from the material being penetrated rather than in direct contact with it. This standoff is provided by the fiber sleeves and metal legs attached to the shaped charge. Table II shows the size of boreholes obtained in concrete, armor, ice, and permafrost by using the standard M3 and M2A3 shaped charges.

e. Special Precautions in Use. In using shaped charges the following precautions should be observed.

(1) The charge should be centered over the point to be attacked.

(2) The axis of the charge should be in line with the direction of the hole desired.

(3) The pedestal provided should be used to obtain the proper standoff distance.

(4) There should be no obstruction in the conical cavity or between the charge and the target since any obstruction will reduce the penetration effect.

(5) Personnel in the open should withdraw at least 900 feet or take appropriate cover before firing due to missile hazard.

17. Bangalore Torpedo

a. Description. The M1A2 bangalore torpedo (fig. 9) consists of a series of loading assemblies which are used singly or in series with

Table II. Size of Boreholes in Various Materials by Shaped Charges

				M3 shaped charge	M2A3 shaped charge
1	Reinforced concrete	Maximum wall thickness which can be perforated (in.).		60 in.	36 in.
2		Depth of penetration in thick walls (in.)		60 in.	30 in.
3		Diameter of hole (in.)	Entrance	5 in.	3½ in.
4			Average	3½ in.	2¾ in.
5			Minimum	2½ in.	2 in.
6		Depth of hole with second charge placed over first hole (in.).		84 in.	45 in.
7	Armor Plate	Perforation (in.)		At least 20 in.	12 in.
8		Average diameter of hole (in.)		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.

nose sleeve and connecting sleeves. They are packed in containers with 10 loading assemblies, 10 connecting sleeves, and a nose sleeve. Each loading assembly is a 5-foot length of steel pipe, 2⅛ inches in diameter and weighing 13 pounds. Of this weight, approximately 8½ pounds is explosive. The explosive used is Composition B. The last 4 inches at each end of the assembly are filled with Composition A–3, high explosive. The sections have cap wells at each end so that they can be assembled in any order. The connecting sleeves are used to make rigid joints. The nose sleeve is used on the front end of the

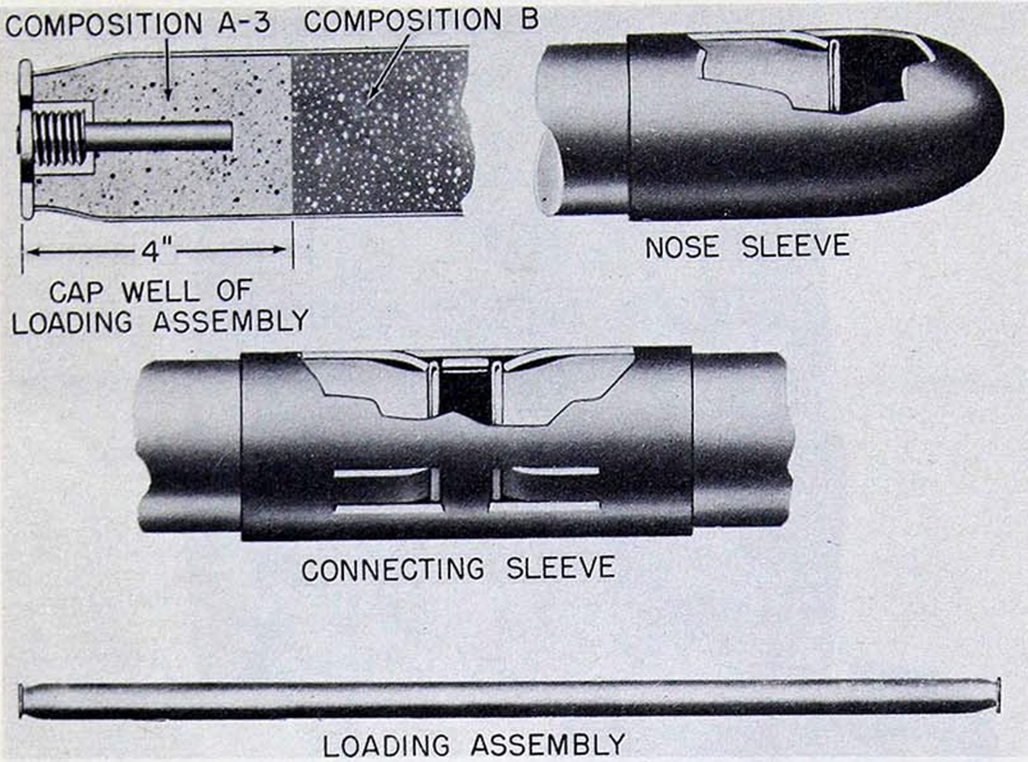
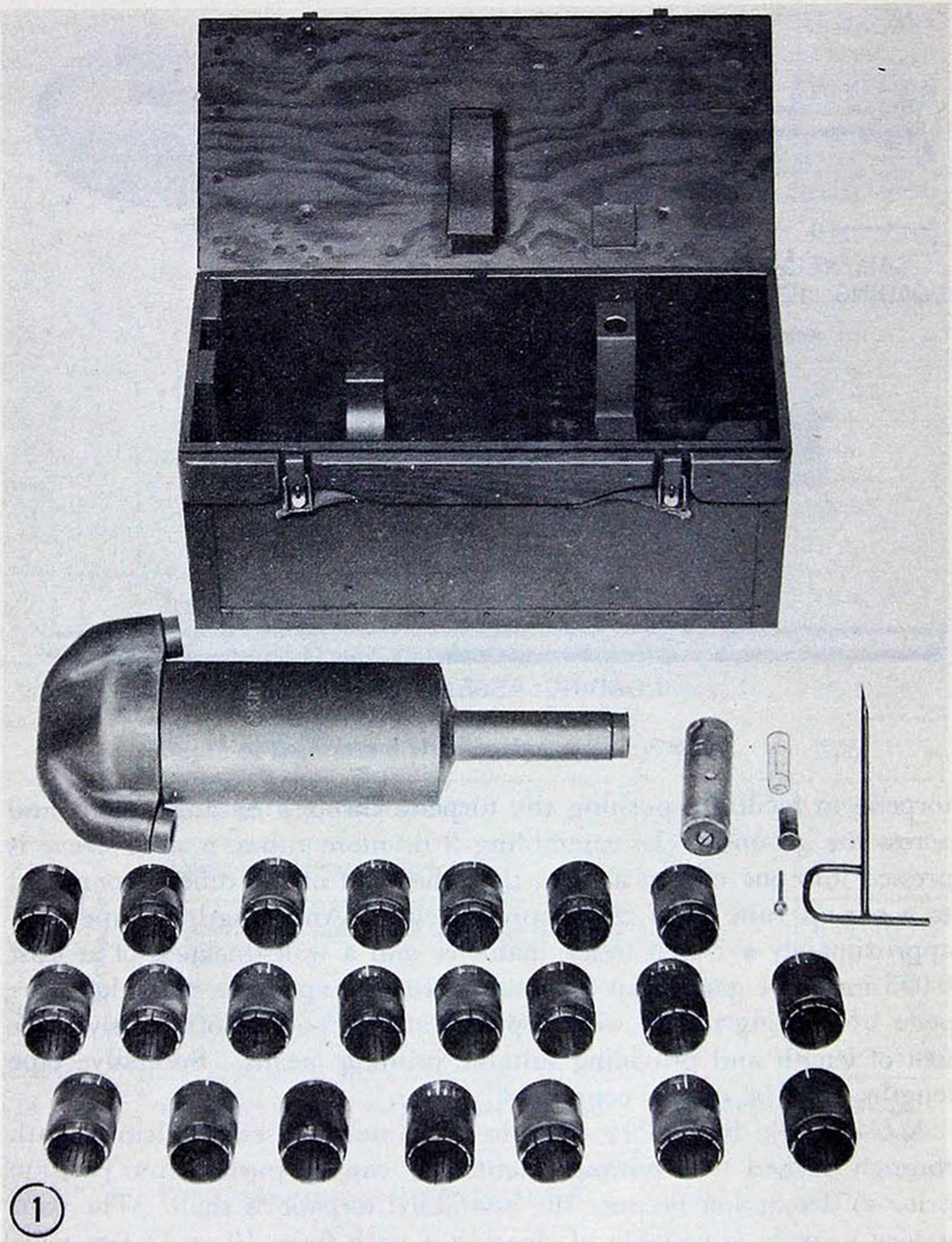


Figure 9. Components of M1A2 bangalore torpedo.

torpedo to facilitate pushing the torpedo through entanglements and across the ground. (In assembling 2 or more tubes, a nose sleeve is pressed into one end of a tube, the other end of the tube is connected to a second tube by a connecting sleeve.) Any length of pipe with approximately a 2-inch inside diameter and a wall thickness of at least 0.025 inch (24 gage) can be made into an expedient bangalore torpedo by packing it well with approximately 2 pounds of explosives per foot of length and providing suitable priming means. Successive pipe lengths must be closely connected.

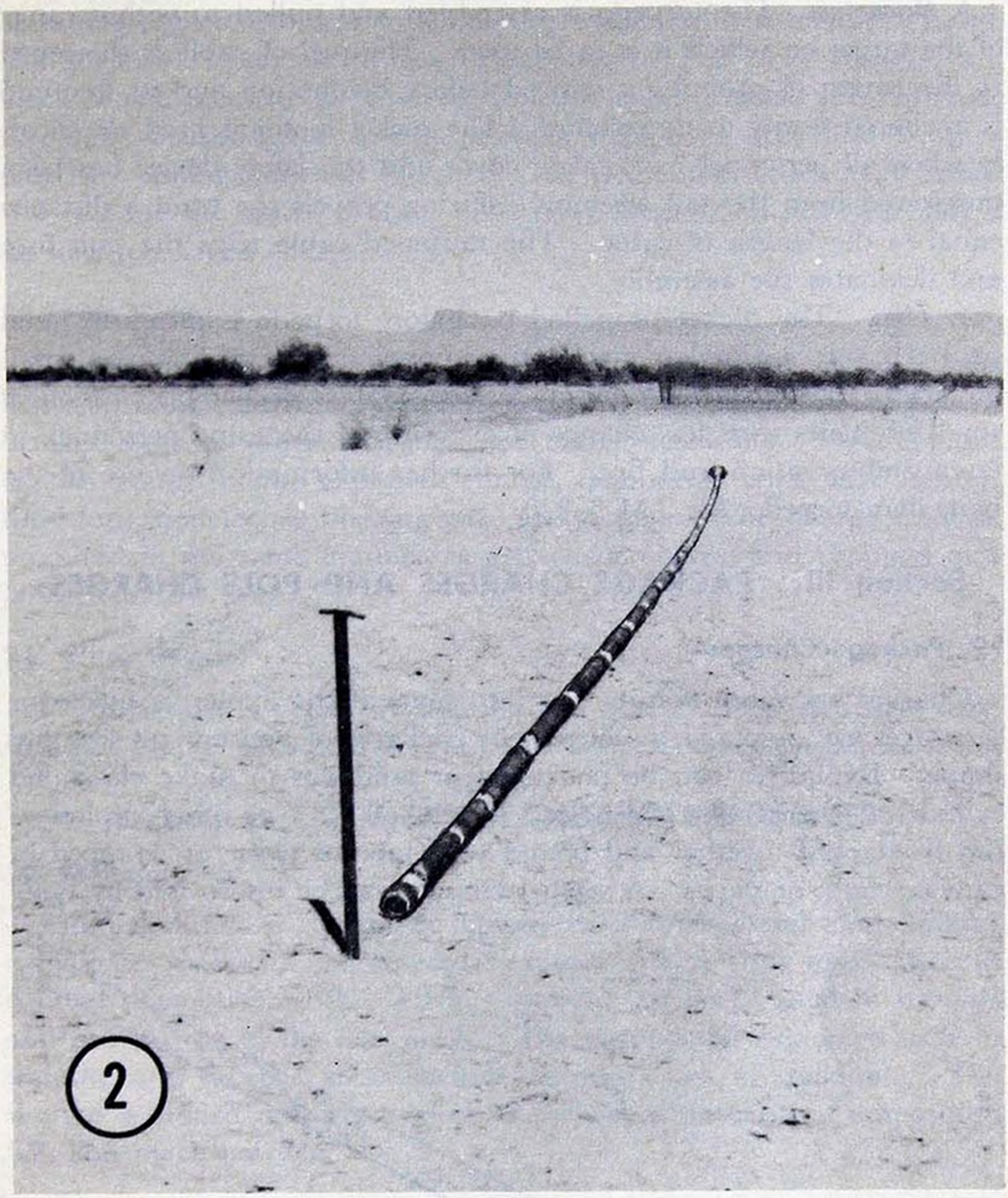
b. Uses. The bangalore torpedo is primarily used to clear a path through barbed wire entanglements. It can be pushed into position prior to detonation because the assembled torpedo is rigid. The bangalore torpedo is capable of clearing a path from 10 to 15 feet wide through a barbed wire entanglement. When this device is so used it will also explode the antipersonnel and most of the antitank mines in a narrower path. The bangalore torpedo may also be used to clear a path through antitank minefields, the concussion of the explosion usually creating sufficient force on the pressure contact fuze mechanisms of the antitank mines to activate them. It should be recognized, however, that the path so cleared is not wide and that some mines may be left in a sensitive state, demanding extreme care in any further mine clearing operations along that path. Bangalore torpedoes may also be used in emergencies for other demolition purposes, particularly against log hurdles and against steel hedgehogs (TM 5-220).



1 Rocket-propelled torpedo set.

Figure 10. Rocket-propelled bangalore torpedo.

c. Detonation. The special blasting cap (electric or nonelectric) will detonate the bangalore torpedo. When using the bangalore torpedo in obstacle clearance, it should be primed after it is in place. The cap well at the end should be protected with tape or a wooden plug while the torpedo is being pushed into place. In tactical uses of the torpedo, the recommended methods of firing are by using a priming adapter, a special nonelectric blasting cap, and time fuze; by using



2 Assembled set, ready for firing.

Figure 10—Continued.

detonating cord with a clove hitch with 2 extra turns around the TNT or Comp A–3 portion of the torpedo; or by using a pull type firing device with a special nonelectrical blasting cap crimped on.

18. Train Bangalore Torpedo, Rocket Propelled

a. Description. This set (1, fig. 10) consists of 20 sections of bangalore torpedo which may be fitted together with special adapters to make a 100-foot train. A kit contains the rocket motors, tail assemblies, and couplings for 20 sections. A rocket motor is fitted to the front of the train to provide propulsion. Detonation is effected by a tail assembly which is fitted to the rear end of the train and contains a pull fuze, a nonelectric blasting cap, and a reel of cable 400 feet long (2, fig. 10).

b. Detonation. The torpedo is assembled and pulled to within range of the target on which it is to be used. The reel of cable is shortened to the length of propulsion desired before detonation and its free end is anchored firmly to the ground. The rocket motor is fired electrically when all personnel have taken cover and the safety device has been unscrewed from the tail assembly. Firing propels the train a distance equal to the length of cable. The tautened cable trips the pull fuze and detonates the assembly.

c. Uses. The rocket propelled bangalore torpedo is primarily used on barb wire entanglements, antipersonnel mines, and similar small obstacles. The rocket propulsion system enables deeper penetration of small obstacles with less chance of exposure of the using personnel, to enemy observation and fire. For further information on use of the bangalore torpedo, see TM 5–220.

Section III. PACKAGE CHARGES AND POLE CHARGES

19. Package Charges

Charges are more readily put into place if the explosive blocks or cartridges are prepared in convenient packages of appropriate size and shape. Explosives can be packaged in sandbags to make elongated cylindrical charges for boreholes. Blocks of TNT or other explosives can be stacked together and bound with tape or twine or wrapped in canvas, cloth, or paper. A satchel charge may be improvised by tying

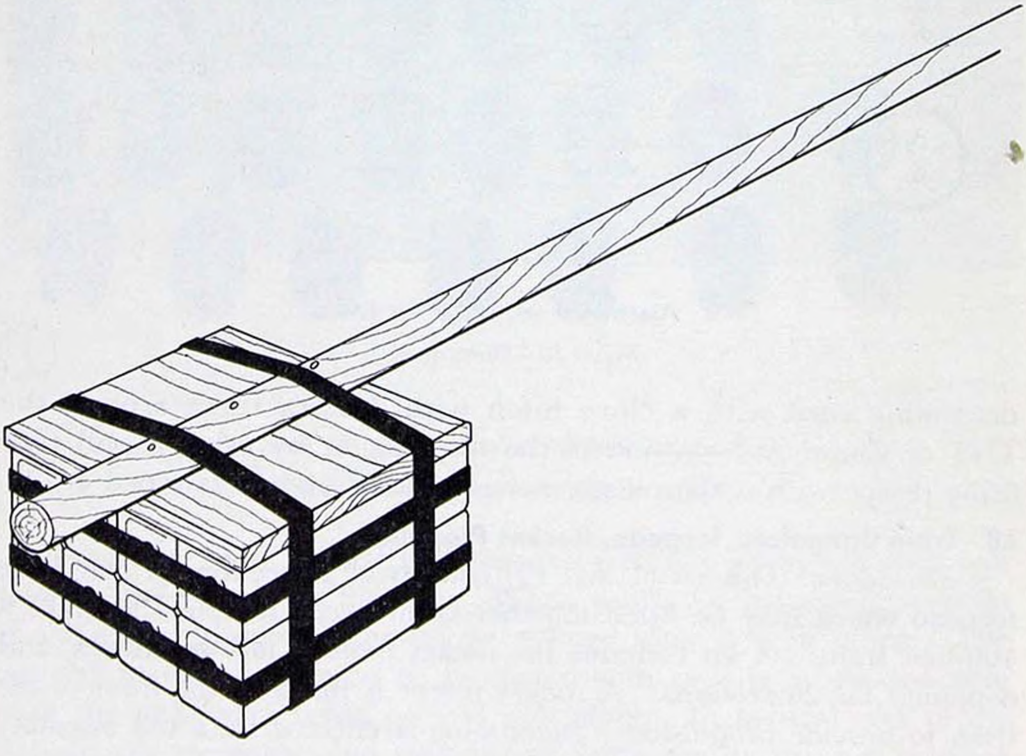


Figure 11. Example of a pole charge.

or taping explosive blocks to a board provided with a handle. Large charges may use an entire case of explosives. For large charges, one block of one cartridge is removed from the case, primed, and replaced. A charge consisting of several cases of explosives may also be prepared by lashing the cases together. The detonation of a single primer will explode the entire charge. The M37 Demolition Kit (par. 66) is an ideal packaged charge.

20. Pole Charges

Pole charges (fig. 11) are convenient for placing charges against pillbox embrasures, hard to reach stringers of bridges, underwater piles of bridges, and in other locations not easily accessible. Pole charges usually consist of the explosive charge, detonating cord, fuze lighter, time fuze, nonelectric blasting cap, and a pole. The charge may be prepared in the same manner as a package charge and propped into position by the pole.

21. Black Powder

Black powder is primarily used for the powder train in a time fuze. It is not normally used as an explosive for demolition purposes.

Section IV. LIMITED STANDARD EXPLOSIVES

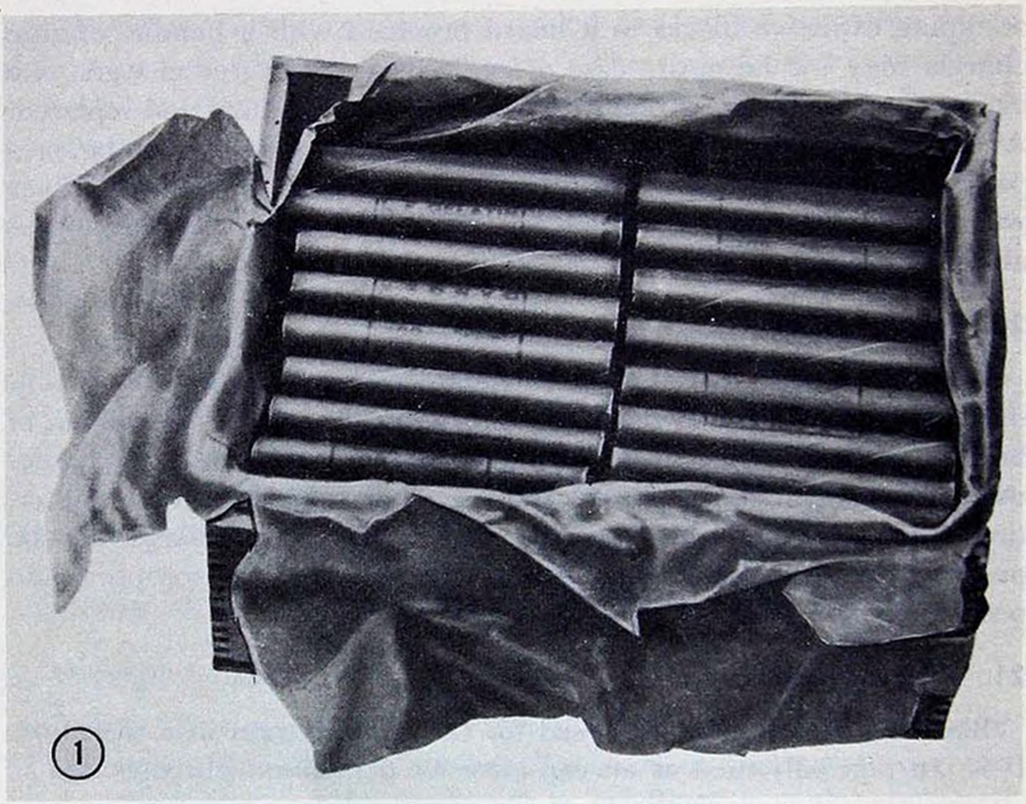
22. General

Limited standard explosives include both commercial and military explosives. Most limited standard explosives have little application in combat demolition work. These explosives are to be used in training and general use in the rear areas. The commercial explosives used in training and in rear areas include various types of dynamite. The limited standard military explosives include nitrostarch, Composition C2, and black powder.

23. Commercial Dynamite

a. Characteristics. Commercial dynamite (fig. 12) is not a standard military explosive primarily because of its undesirable characteristics. The general composition of commercial dynamite is liquid nitroglycerin absorbed in a porous filler. The most common types of commercial dynamite used in military work are listed in table I. Commercial dynamite must be handled with caution because flame, sparks, friction, and sharp blows can detonate it. It is subject to relatively rapid deterioration and requires special surveillance. Commercial dynamite is exploded by a No. 6 or larger commercial blasting cap or by Corps of Engineers special blasting caps.

(1) Straight dynamite contains nitroglycerin as the explosive ingredient and a nonexplosive filler. It has a high velocity of detonation which produces a shattering action. Straight



1 Case opened.

Figure 12. Dynamite.

dynamite is water resistant to a small degree and may be used underwater only if fired within 24 hours after submersion.

(2) Ammonia dynamite contains ammonia nitrate, in addition to nitroglycerin, as the explosive base. It has a medium velocity of detonation which produces a heaving action. It is not satisfactory for underwater use.

(3) Gelatin dynamite is a jelly made by dissolving nitrocotton in nitroglycerin. It is highly water-resistant, and suitable for use in wet conditions.

b. Uses. Commercial dynamite is not used in forward areas because of its sensitivity to shock and to friction. However, lack of other and more suitable explosives may necessitate its use in cases of emergency. Fifty percent straight dynamite is approximately equal in strength to TNT. Gelatin dynamite is suitable for underwater use. Dynamite is used for land clearing, cratering, and quarrying operations. A gelatin dynamite of low heaving force and high rate of detonation is used for hard rock. A composition having great heaving force and low rate of detonation is preferable for blasting earth or soft rock.

24. Nitrostarch

Nitrostarch is slightly less powerful than TNT. It is very sensitive to flame, friction, and impact. Never attempt to crush or crumble

2 An open stick.

Figure 12—Continued.

nitrostarch; it is liable to detonate if struck sharply. Nitrostarch should not be detonated in closed spaces because it produces poisonous gases when it explodes. Nitrostarch is no longer manufactured; however, it is still available for issue. Nitrostarch is not consistently exploded by a cap less powerful than the special electrical or nonelectrical blasting cap. More powerful priming means can be used, including the tetryl blasting cap (electrical or nonelectrical), various detonators, and detonating cord.

25. Composition C2

Composition C2 is a plastic explosive more powerful than TNT and of about the same sensitivity. It is fair as a cratering charge. Composition C2 is not consistently exploded by a cap less powerful than the special electrical or nonelectrical blasting cap. More powerful priming means can be used, including the tetryl blasting cap (electrical or nonelectrical), various detonators, and detonating cord.

Section V. FOREIGN EXPLOSIVES

26. General

The most common explosives used by foreign countries are TNT, picric acid, and guncotton. Picric acid has almost the same characteristics as TNT except that it corrodes metals and forms extremely sensitive compounds. A picric acid explosive found in a rusted or corroded container must not be used. When found in this condition, it should be handled very carefully, moved to an appropriate location, and detonated.

27. Uses

Captured enemy explosives and those of allied nations should, whenever possible, be used to supplement standard supplies. This practice should, however, be undertaken only by experienced personnel in accordance with instructions and directives issued by theater commanders. Captured bombs, propellants, and other firing devices can be used with U.S. military explosives for large demolition projects such as pier, bridge, tunnel, and airfield destruction. Foreign explosives are generally less sensitive than U.S. military explosives and, therefore, require the use of a booster of TNT or some other suitable explosive to insure positive detonation. Most foreign explosive blocks have cap wells sufficiently large to receive U.S. special blasting caps. Special blasting caps, when used to detonate foreign explosives, should be tested on a single block before being used extensively.

CHAPTER 3

SAFE HANDLING AND STORAGE OF EXPLOSIVES

Section I. HANDLING PRECAUTIONS

28. General

Explosives are dangerous when not handled properly. Carelessness, rough handling, and disregard for safety rules cause unnecessary waste, premature explosions, misfires, and, in many cases, serious accidents. Demolition explosives and related items are packed to withstand conditions ordinarily encountered in the field, being packed for shipment and storage in moisture-resistant containers and suitable packing boxes. However, containers and boxes must not be handled roughly. Care must be taken to keep packing boxes and containers from being broken, cracked, or dented. Some specialized items may lose part of their effectiveness if distorted. If packing boxes and containers should become damaged, they must be repaired immediately and careful attention given to transferring all defaced parts of markings to new parts of the box. If airtight containers, such as the ones used for chemical mines, are broken, they should be destroyed.

29. TNT and Tetrytol

Solid TNT is a relatively safe material to handle but molten TNT may be extremely hazardous. Fragments of TNT and tetrytol should not be permitted to accumulate and should be destroyed promptly.

30. Ammonium Nitrate Cratering Charge

The container for the ammonium nitrate cratering charge can be easily punctured. Therefore, extreme care must be exercised in handling the container. If the container is punctured, rapid absorption of moisture follows, and the explosive charge may be rendered ineffective.

31. Shaped Charges

Shaped charges are cast cone-shaped to obtain the best results. Cracks, breaks, or dents destroy this shape and decrease the effectiveness of the charge.

32. Commercial Dynamite

Commercial dynamite is more sensitive to heat and shock than any of the other commonly used explosives. The nitroglycerin content tends to settle to the bottom of the cartridge and to drain from the dynamite. To minimize leakage, cases of dynamite are stored top side up so the cartridges lay horizontally (1, fig. 12). To counteract the concentration of nitroglycerin due to its settling, cases of straight dynamite are turned as follows:

Below 30° F	Not turned.
30°–60° F	Every six weeks.
60°–75° F	Monthly.
Over 75° F	Every two weeks.

Commercial dynamites are currently manufactured with freezing depressants added to lower the freezing point and to make the dynamite more reliable at low temperatures. However, some commercial dynamites, which were originally manufactured for use in warm climates, may freeze.

33. Old Dynamite

Dynamite can be determined to be old if an oily substance appears on the casing of the sticks or if stains appear on the wooden packing case. Oiliness on the individual sticks and stain on the packing case are caused by the separation of the nitroglycerin from the porous base. Dynamite in this state is extremely sensitive. It must not be used. It should be destroyed immediately by burning. TM 9–1900 contains information on the disposal and destruction of explosives.

34. Frozen Dynamite

Frozen dynamite can be detected by hardness of the stick and by the appearance of crystals in the contents of a stick. Frozen dynamite is destroyed by burning, in the same manner as old dynamite. If it is necessary, however, to use frozen dynamite, it must be thawed before using, as follows:

a. A thawing kettle, similar to the commercial type shown in figure 13, is used. When a commercial type container is not available, a 5-gallon kettle and a 10-gallon kettle from the unit mess may be combined to make a thawing kettle.

(1) Water is heated in a separate container to a temperature as hot as can be tolerated by the hand.

(2) The heated water is poured into the water compartment of the thawing kettle.

(3) The frozen dynamite is laid in the inner compartment, in a horizontal position, so that air can circulate readily around it.

(4) The kettle is placed in a barrel or box and surrounded with hay or similar insulating material.

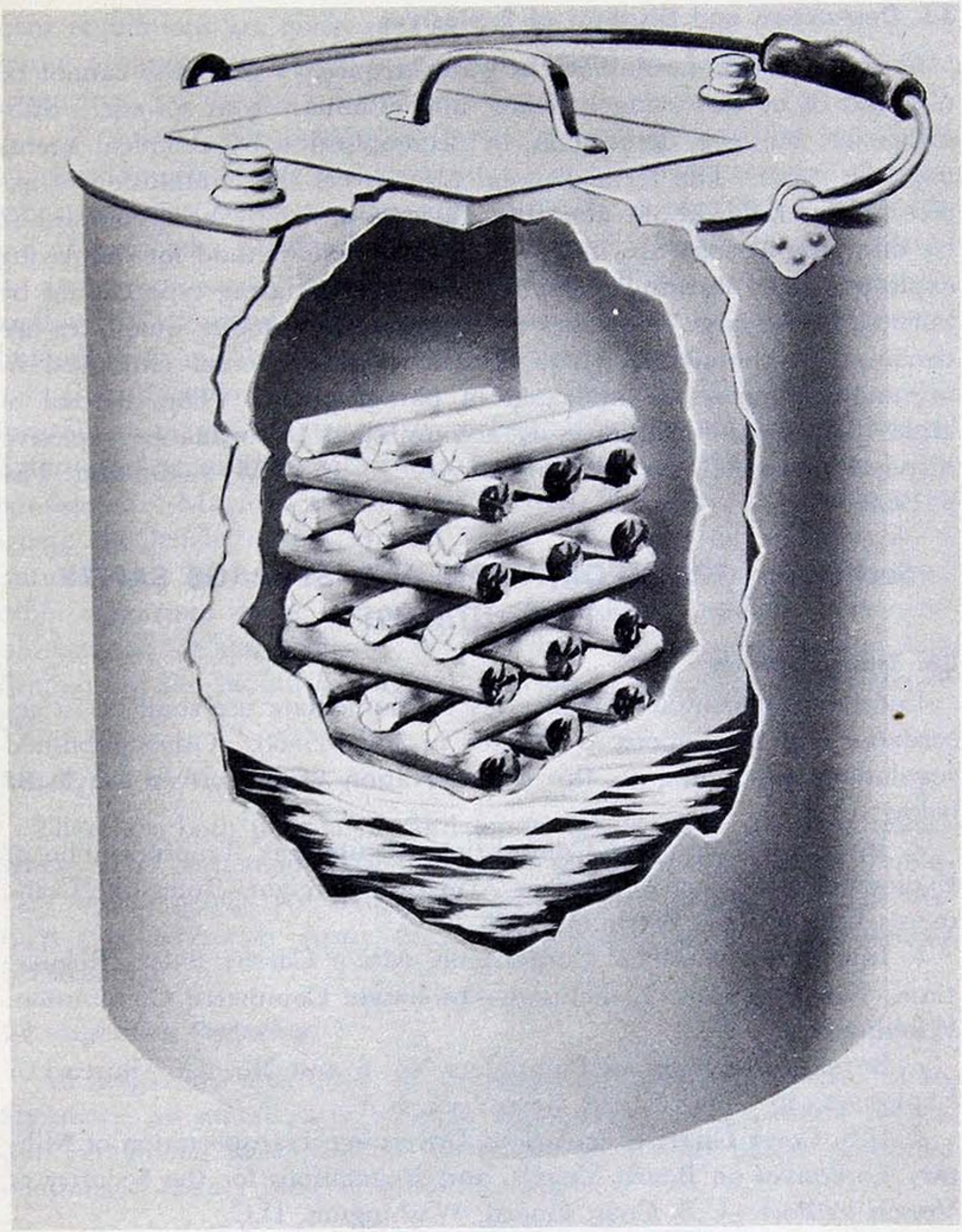


Figure 13. Dynamite thawing kettle.

(5) Not more than 50 pounds of frozen dynamite is thawed in 1 lot.

(6) The frozen dynamite is never placed in the explosive compartment before the hot water is poured into the water compartment of the kettle.

(7) The kettle is never placed over heat after the dynamite is in it.

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

35. Destruction and Disposal of Explosives

Because of their insolubility in water, explosives generally cannot be disposed of by dissolving in water and eliminating as sewage. Submergence, burning, detonation, or decomposition by chemical agents must be used. The term disposal also covers the elimination of explosive material without alteration in form and may be accomplished by dumping at sea (SR 75–70–10). The best method for destroying explosives is by burning. Explosives of the initiating type cannot be burned, hence large quantities are detonated. Smaller quantities are decomposed chemically. Safe distances for personnel employed in burning explosives are indicated in paragraph 43. The disposal of large quantities of explosives is accomplished by ordnance explosive disposal personnel as directed in AR 75–15, FM 9–40, and TM 9–1900.

Section II. TRANSPORTATION AND STORAGE SAFETY PRECAUTIONS

36. Transportation

Local transportation of explosives for immediate use shall be in accordance with regulations as directed in AR 385–68. Other published regulations pertaining to the transportation of explosives are listed below.

a. Interstate Commerce Commission Regulations, Transportation of Explosives and Other Dangerous Articles by Freight—Interstate Commerce Commission, Washington 25, D.C.

b. Interstate Commerce Commission, Motor Carrier Safety Regulations, Part Nos. 1 to 7, inclusive—Interstate Commerce Commission. Washington 25, D.C.

c. Bureau of Explosives Pamphlets No. 6 and No. 6A—Bureau of Explosives, 30 Vesey Street, New York, N.Y.

d. U.S. Coast Guard Regulations Governing Transportation of Military Explosives on Board Vessels, and Regulations for the Security of Vessels in Port—U.S. Coast Guard, Washington, D.C.

e. U.S. Department of Commerce, Bureau of Marine Inspection and Navigation Regulations Governing Transportation, etc., of Explosives—Department of Commerce, Washington, D.C.

f. U.S. Civil Aeronautics Board, Civil Air Regulations, Part 49, Transportation of Explosives and Other Dangerous Articles—Civil Aeronautics Board, Washington, D.C.

g. Freight Tariff No. 10—H. A. Campbell, Agent, 30 Vesey Street, New York, N.Y.

37. Magazine Location

a. General. The storage of explosives in magazines must conform to rigid safety regulations because of the destructive effects. The pertinent regulations are given in TM 9–1903. Table III gives the minimum distances at which magazines should be located from other magazines, buildings, and routes of communication.

b. Barricades. For certain explosives, natural or artificial barricades which effectively screen a storage magazine reduce by one-half the distance necessary between magazines, railways or highways. Thus the use of barricades permits the storage of larger quantities of explosives in any given area. Barricades are designed to protect magazines against the damaging effects of explosions, bomb or shell fragments, but not from missile damage or fire-exposure hazards.

c. Other Considerations. Among other factors which determine the location of magazines are safety, accessibility, dryness, and drainage. Safety and accessibility are the most important of these factors to be considered. Magazines should be located, if possible, in a hilly area where the height of the ground above the magazine will provide a natural wall or barrier to buildings, center of communication, and other magazines in the area. The use of sidehill dugouts is undesirable because of the difficulty of providing adequate ventilation and drainage. Site should be cleared of brush to minimize the danger of fire.

38. Types of Magazines

There are both permanent and temporary types of standard magazines. The permanent type magazines are preferred, but the temporary or emergency type magazines may be used in lieu of the permanent type whenever Army construction policy prohibits permanent construction.

39. Lightning Protection

All magazines must have an overhead lightning rod system. Furthermore, all metal parts, such as doors, ventilators, window sashes, and reinforcing steel must be connected in several places to buried conduits of copper plate or graphite rods.

Table III. Magazine Location (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

40. Field Expedient Structures

a. Types of structures which may be used as field expedients for the storage of explosives, when magazine construction is not possible, are given below. Quantities stored should be considerably less than indicated in table III.

(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 boxhouse, with a wedge type roof, covered with corrugated iron.
(4) A light wooden frame as described in (3) above and covered with a tent or with a canvas tarpaulin.

b. Field expedient storage facilities should be marked by appropriate signs on all four sides or guarded by personnel so posted as to keep all approaches under surveillance. Explosives should always be locked in a substantial structure or kept under guard.

41. Temporary Magazines and Storage in Training Areas

When it is desired to store a day's supply of explosives within reasonable distance of the point of use, covered ammunition shelters are to be used. Explosives should be separated so that fire or explosion will not be communicated from one shelter to another. When temporary open storage is used, no pile should exceed 500 pounds of explosives, if practicable, and distances between piles should not be less than 140 feet. Explosive components should be segregated and placed in separate piles. When explosives, caps or other explosive components are stored temporarily in a training area, a guard will be provided at all times.

42. Safety Rules

Safety rules in relation to explosives, caps, and demolition equipment will be strictly followed in training. The safety regulations for the conduct of training are given in AR 385–63. In all other situations, they will be observed to the fullest extent permitted by time, by materials available, and by the requirements of the mission. The general rules apply to all explosive materials and situations.

a. Explosives are never to be handled carelessly.

b. Responsibility for the preparation, the placement, or the firing of charges is never to be divided. One person is to be made responsible for the supervision of all phases of a demolition mission.

43. Safe Distance Formula

The following criteria gives the missile hazard distances at which personnel in the open are safe from missiles created by bare charges placed in or on the ground, regardless of type or condition of the soil.

The safe distance formula for explosive charges placed on or in the ground is—

$$\text{Safe distance in feet} = 300 \times \sqrt[3]{\text{pounds of explosives}}$$

Table IV. 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	1–65	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	2, 400
60	1, 170		

Note. Chart is based upon formula: $d=300 \times 3\sqrt{P}$ for charges from 27 to 500 pounds
d= Safe distance in feet
P= Pounds of explosive

CHAPTER 4
DEMOLITION EQUIPMENT

Section I. BLASTING EQUIPMENT AND ACCESSORIES

44. Blasting Caps

a. General. Blasting caps, used for priming explosives, are the Army types and the commercial types. The Army type consists of a thin tubular metallic shell of noncorrosive material about 2½ inches long and ¼-inch diameter containing an initiating composition and a charge of tetryl or PETN, which are sensitive high-explosives. Blasting caps are used for initiating high explosives and as the detonating element for certain types of landmine fuzes. The caps are designed to be inserted into cap wells; the electric type being fitted with lead wires for attachment to a blasting machine and the nonelectric type crimped to any standard firing device or to time blasting fuze (safety fuze) fitted with a fuze lighter. Special Army electric (type II (J2 PETN)) and nonelectric (type I (J1 PETN)) caps are used to detonate the less sensitive military explosives such as TNT and ammonium nitrate. Commercial caps, principally the No. 6 and No. 8, may be used to detonate the more sensitive explosives, such as tetryl, tetrytol, or nitrostarch. The No. 8 cap is more powerful than the No. 6, hence the No. 8 cap may be used to detonate a less sensitive explosive than one which can be detonated by a No. 6 cap. Caps, blasting, No. 8, first, second, third, and fourth delay are used to detonate charges of commercial dynamite (or lengths of detonating cord) in a sequence, especially in quarrying or tunnel driving operations.

b. Storage and Handling. Blasting caps are extremely sensitive and may explode unless handled carefully. They must be protected from shock and extreme heat and must not be tampered with. They are never to be stored with any other explosives. Caps and explosives must not be carried on the same truck except in emergency (par. 36).

45. Electric Blasting Caps

a. Examples of delay blasting caps which are issued are shown in figure 14. While only the 1st and 3d delay caps are shown in that figure, there are issued 1st, 2d, 3d, and 4th electric delay blasting caps. The approximate time delays for these various caps are 1 second for 1st delay, 1.18 seconds for 2d delay, 1.35 seconds for 3d delay,

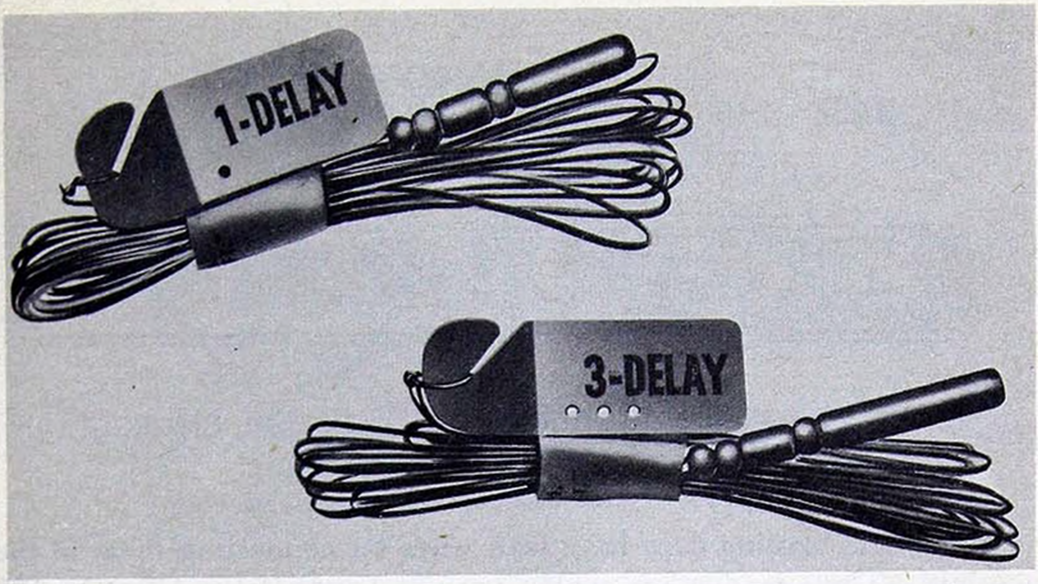


Figure 14. Electric delay blasting caps.

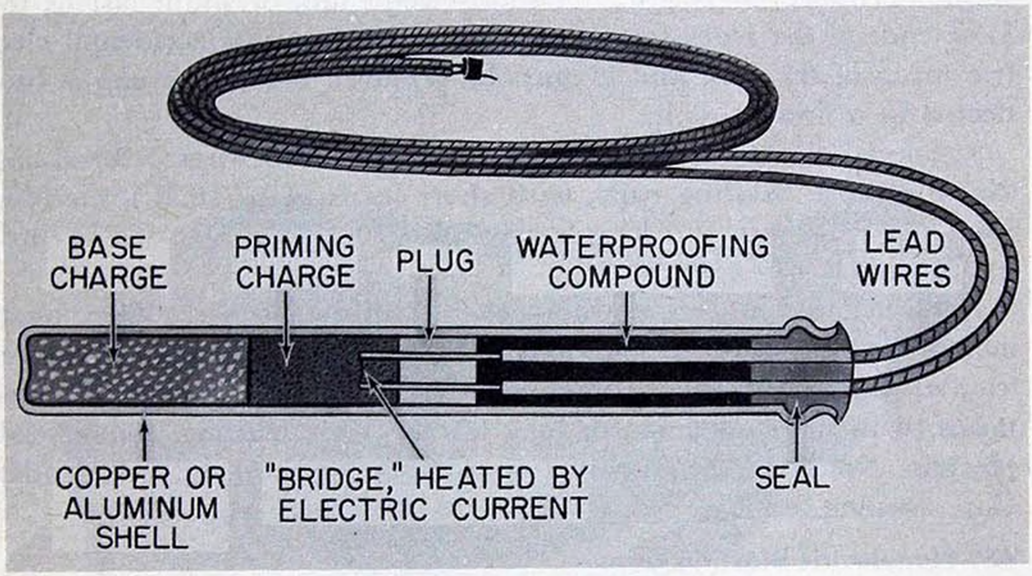


Figure 15. Typical construction of an electric blasting cap.

and 1.53 seconds for 4th electric delay blasting caps. Commercial delay caps up through 10th delay (approximately a 2.50 second delay) exist but these are not items of military issue. The commercial millisecond electric delay blasting caps are likewise not items of issue. Figure 15 shows the details of construction for a typical electric blasting cap.

b. When two or more electric blasting caps are connected in the same circuit, they must be products of the same manufacturer. This is essential to prevent misfires, because blasting caps of different manufacturers do not have the same electrical characteristics. Blasting caps made by any one manufacturer can be identified by the label and the color of the cap.

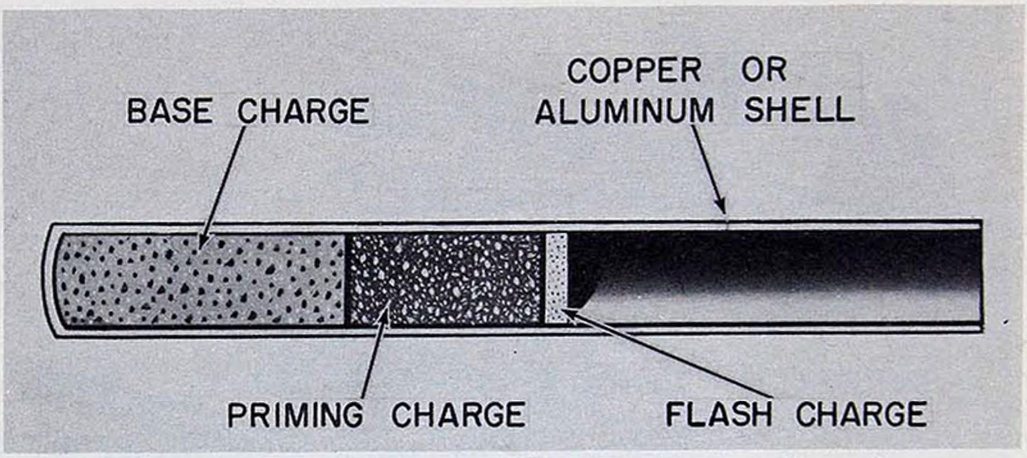


Figure 16. Typical construction of a nonelectric cap.

c. Electric blasting caps have lead wires for connecting them in the circuit. These lead wires, which vary in length from 4 feet to 100 feet, enter the blasting cap through a seal (fig. 15) which may be of sulphur, rubber, or plastic. A short-circuit tab, or shunt fastens the loose ends of the wires together. This shunt prevents accidental electric firing of the cap, and it must be removed before the cap is connected in a firing circuit.

d. Special electric blasting caps have 12-foot lead wires. No. 6 and No. 8 electric blasting caps, with short leads (4 to 10 ft.), medium leads (12 to 40 ft.), and long leads (50 to 100 ft.) are carried in Ordnance stocks.

e. Electric blasting caps which are currently issued are—Cap, blasting, special, electric (type II (J2 PETN)). Cap, blasting, tetryl, electric, waterproof. Cap, blasting, commercial, electric, No. 6, instantaneous (with short, medium, or long leads). Cap, blasting, commercial, electric, No. 8, instantaneous (with short, medium, or long leads). Cap, blasting, electric, No. 8, delay (1st, 2d, 3d or 4th delay).

46. Nonelectric Blasting Caps

a. Details of a typical nonelectric blasting cap are shown in figure 16.

b. Nonelectric blasting caps which are currently issued are—Cap, blasting, special, nonelectric (type I (J1 PETN)). Cap, blasting, tetryl, nonelectric. Cap, blasting, nonelectric, No. 6, instantaneous. Cap, blasting, nonelectric, No. 8, instantaneous.

c. Because a nonelectric blasting cap is extremely difficult to waterproof, its use should be avoided in priming charges placed under water or in wet boreholes. Such charges, if they are to be fired nonelectrically, should be primed with detonating cord, as explained in paragraphs 68 and 69, and the nonelectric blasting cap fastened to the detonating cord above the water or ground level. If it becomes necessary to use nonelectric blasting caps in damp boreholes, they should be covered with a waterproofing compound and fired immediately after being placed.

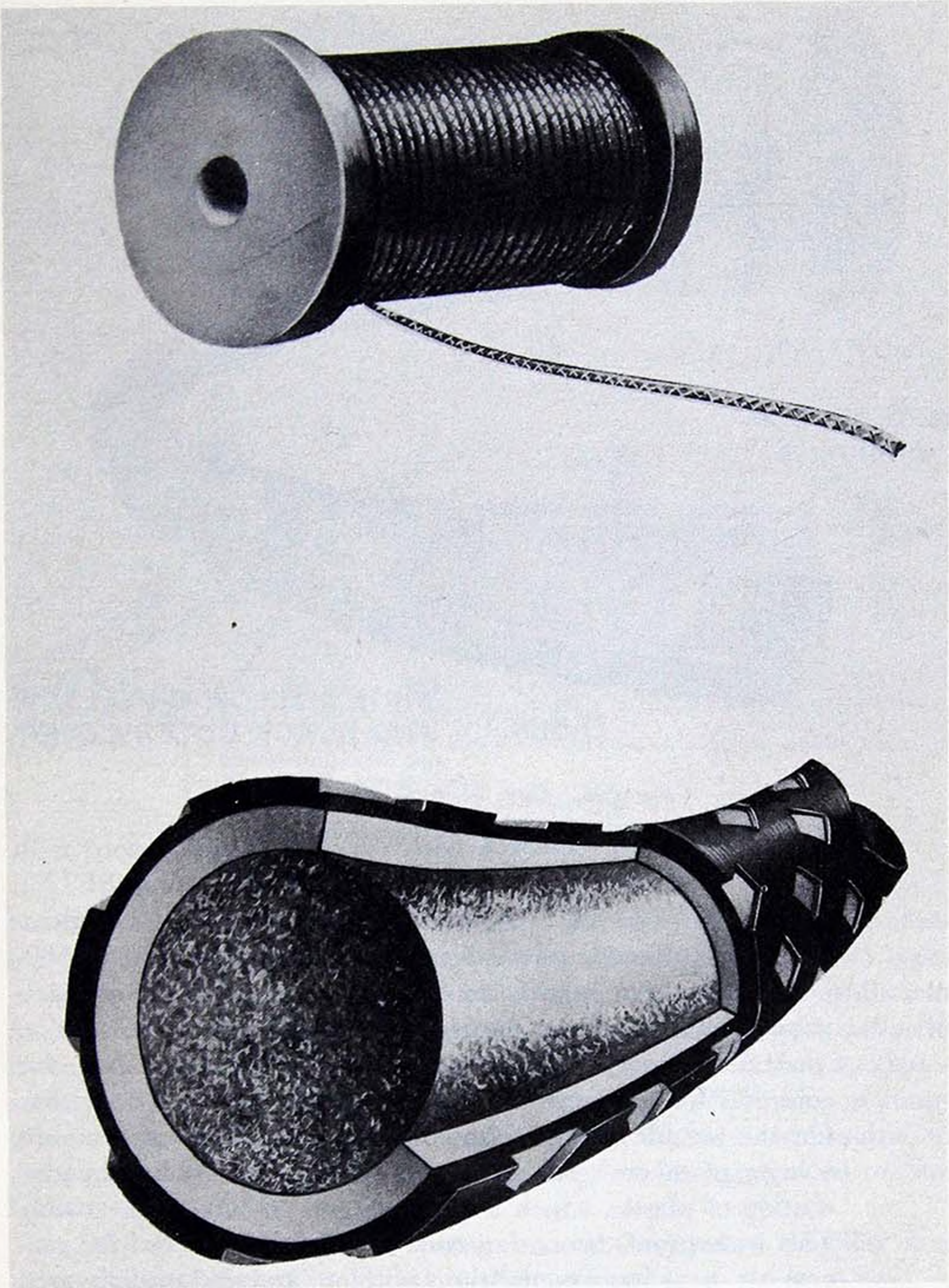


Figure 17. Cord, detonating (PETN, fuze).

47. Detonating Cord

a. Description.

(1) Cord, detonating (PETN) (fig. 17) consists of a flexible tube filled with PETN contained within a white, yellow, or yellow and black waterproof textile covering. It will detonate even when the core is water-soaked, provided the detonation is started from a dry end. Its detonation may be initiated with the special blasting cap, electric or nonelectric. The explo-

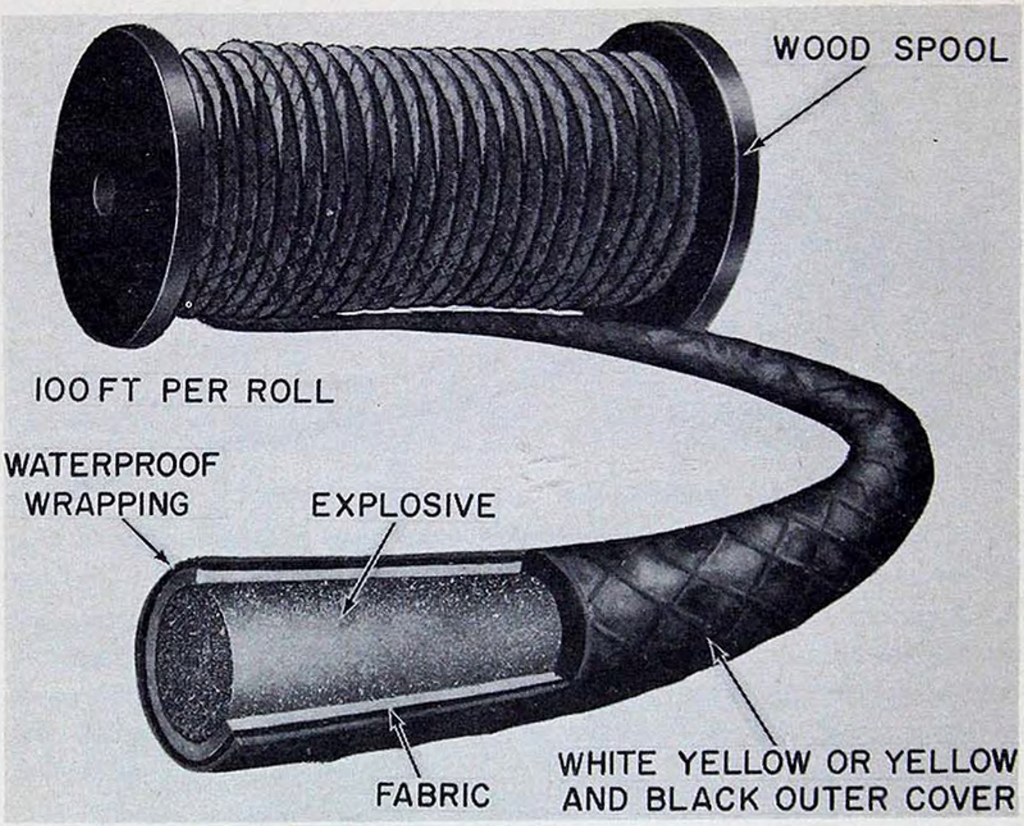


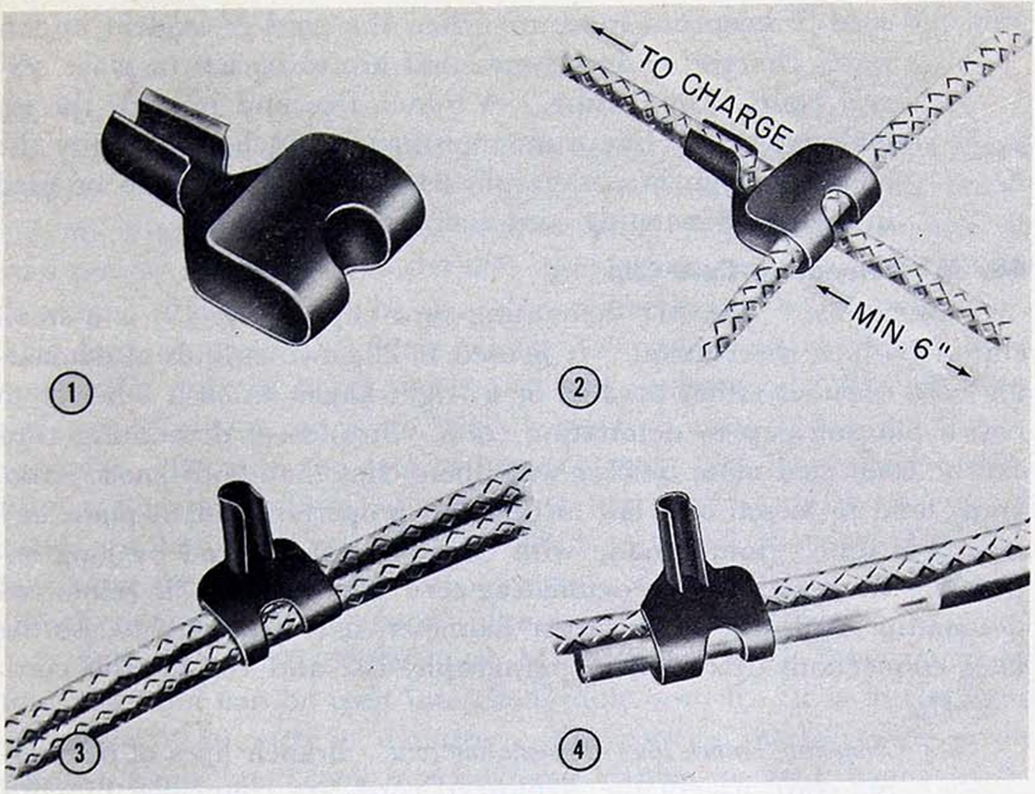
Figure 18. Cord, detonating, waterproof.

sion of any high explosive with which detonating cord is in contact will also detonate the cord. Cord, detonating (PETN), is issued in 50-, 100-, 500-, and 1,000-foot spools. Cord, detonating, reinforced, pliofilm wrapped, is issued only in 500-foot spools. For information on approved knots for connecting detonating cord, see paragraphs 102 and 103.

(2) Cord, detonating, waterproof (fig. 18) consists of an explosive core of PETN contained in a braided seamless cotton tube. On the outside of this tube is a layer of asphalt on which is a layer of rayon. All are covered by a continuous extruded coating of plastic, which is colorless and smooth to the touch. This waterproof detonating cord is the standard cord for general use in military demolitions both on land and under water.

(3) Cord, detonating, reinforced, pliofilm wrapped, is similar to the cord described in (1) above, except in the covering, which is designed for vigorous use and severe weather. The plastic wrapping increases the tensile strength of the cord from 150 pounds to 250 pounds. The plastic covering also makes the cord more stable in abnormally high temperatures, and decreases the possibility of the wrapper losing the waterproof qualities when handled.

b. Uses. Detonating cord is used to prime charges and to simul-



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

Figure 19. M1 detonating-cord clip and methods of use.

taneously explode a number of separate charges. Reinforced detonating cord is used for the same purposes as detonating cord. All 3 types of cords detonate at a high rate (21,000 ft./sec.) and with sufficient force to detonate other explosives to which the cord has been properly attached. Detonating cord is particularly useful for initiating explosives placed below ground, especially where a foot or more of stemming above the explosive would make it difficult, if not impossible, to set off a misfire by propagation from another charge placed on the surface.

c. Safety Precautions. Safety measures to be observed in handling and using detonating cord and reinforced detonating cord are as follows:

(1) Kinks and sharp bends are to be avoided.

(2) Special handling care is to be exercised in cold weather to avoid breaking either the covering or the explosive train.

(3) Detonating cord lines are to be laid out as straight as possible but not stretched taut. Detonating cord tends to form a spiral as it is unwound from its spool. To avoid misfire it must be carefully straightened before firing.

(4) No part of the detonating cord fabric covering is to be removed.

(5) A sealing compound is to be applied to the end of detonating

cord to keep out moisture when the cord is used in underwater charges, or in charges that are to be left in place several hours before firing. A 6-inch free end protects the remainder of the line from moisture for 24 hours. Only the methods given in paragraphs 94 through 105 are to be used in making detonating cord connections.

48. M1 Detonating-Cord Clip

a. Description. The M1 detonating-cord clip (1, fig. 19) is a small clip of 1/64-inch sheet metal. It is used to clip two strands of detonating cord together either parallel or at right angles to each other or to clip a blasting cap to detonating cord. Strands of detonating cord can be connected more quickly with these clips than with knots. Also, knots tend to loosen and fail to function properly if left in place any length of time. Joints made with clips are not affected by long exposure. Because the M1 detonating-cord clip will not fit reinforced detonating cord, due to its larger diameter, it is necessary to use the knot connections described in paragraphs 102 and 103 for this cord.

b. Use.

(1) *Connecting branch lines of detonating cord.* Branch lines of detonating cord, except the reinforced cord, are connected by clipping the branch line with the U-shaped trough, and the main line with the tongue of the clip, as shown in 1, figure 19. 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 in place by bending the tongue back into place. If time permits, the connection is improved by crimping the clip around each strand.

(2) *Connecting two ends of detonating cord.* Ends of detonating cord are spliced by overlapping the ends about 12 inches, placing the clip at the middle of the overlap, and bending the tongue of the clip firmly over both strands. The connection is made secure by bending the trough end of the clip back over the tongue (3, fig. 19).

(3) *Priming detonating cord.* Detonating cord is primed by clipping a blasting cap to the cord, or by taping a blasting cap to the cord. Any of the issued electric or nonelectric blasting caps will fire the detonating cord. 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 19. The trough is then bent back over the tongue to secure the connection. When priming detonating cord, a more instantaneous blast must not be attempted by inserting the caps in separated position, be-

cause the caps will detonate the cord between them but may not detonate the balance of the trunkline.

49. Time Fuzes

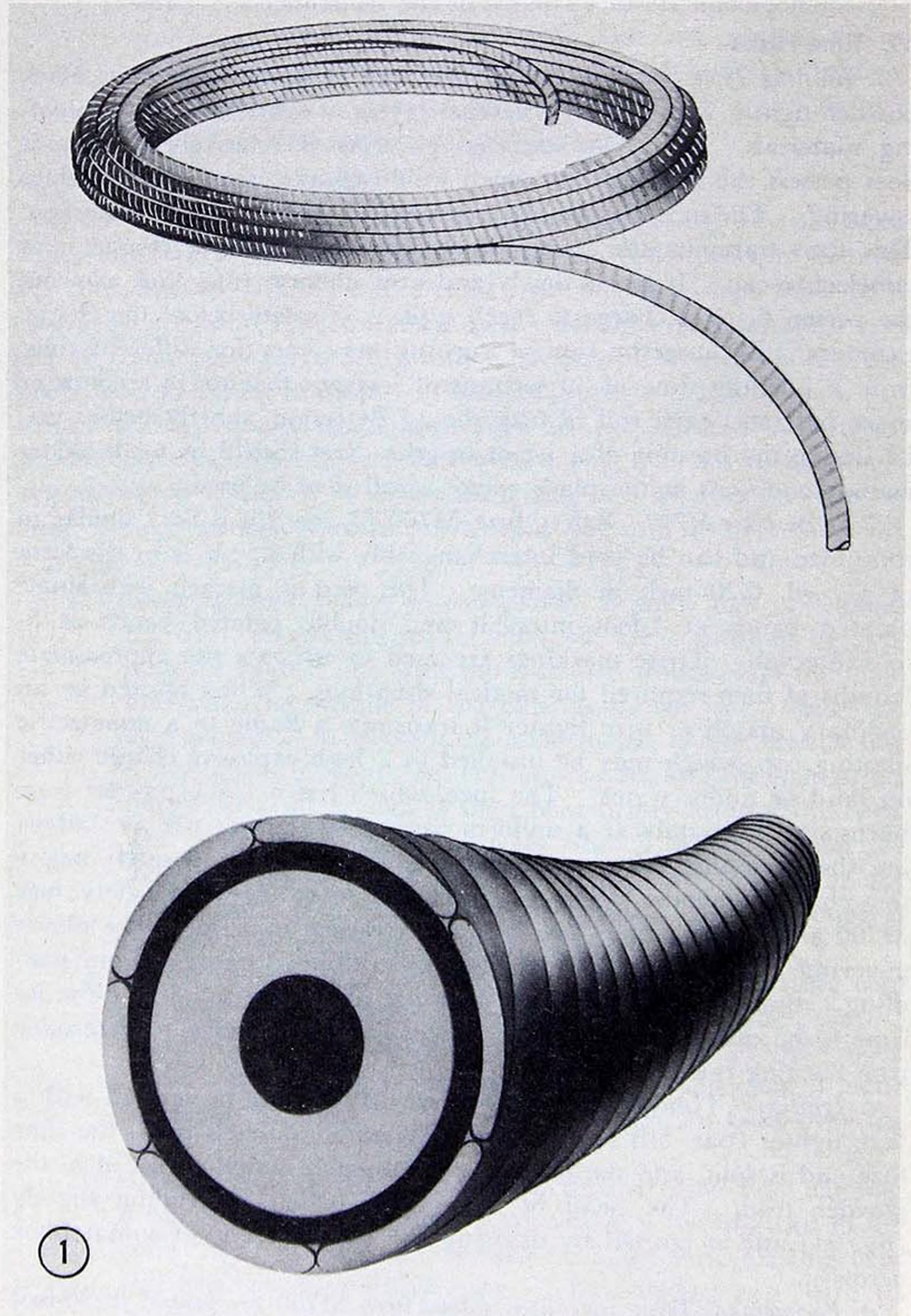
a. Blasting Time Fuze. Blasting time fuze (1, fig. 20) contains black powder tightly wrapped with several layers of fabric and waterproofing materials. While the external covering is relatively smooth, it does possess the corrugations which would characterize a heavy fabric covering. The fuze may be any color, orange being the most common. This fuze transmits the flame which fires the explosive charge in a nonelectric cap. It burns slowly and at a uniform rate, thus allowing the person firing a charge to reach a place of safety before the charge explodes. Because the rate of burning may vary for different rolls, from a burning time of 30 seconds or less per foot to 45 seconds or more per foot, each roll of fuze should be tested, shortly before use, by timing the burning of a 1-foot length. Test should be made under actual conditions at the place where a roll is to be used.

b. Safety Fuze M700. Safety fuze M700 (2, fig. 20) is very similar to time fuze and can be used interchangeably with it. It is in the form of a cord, 0.20 inch in diameter. The cord is marked with single painted bands at 1-foot intervals and double painted bands at 5-foot intervals. These markings are used to estimate the approximate lengths of fuze required for tactical situations. When ignited by an ordinary match or fuze lighter it transmits a flame to a nonelectric blasting cap, which may be installed in a high explosive charge either on land or under water. The fuze, which has a black powder core, burns approximately at a uniform rate of 40 seconds per foot allowing the personnel firing a charge to walk to a place of safety before the charge explodes. The essential difference between safety fuze M700 and blasting time fuze is in the covering material. The plastic covering is more durable and less susceptible to damage from handling. Burning rates for safety fuze are about the same as those for time fuze, and the same test (*a* above) is recommended to determine true burning rate.

c. Ignition. Time fuze or safety fuze M700 may be ignited with a fuze lighter (par. 50) or a match. When a match is used, the time fuze end is split, and the head of an unlighted match is placed in the powder train. The head of the match is left protruding slightly (fig. 21) and is ignited by drawing the abrasive side of a matchbox across it.

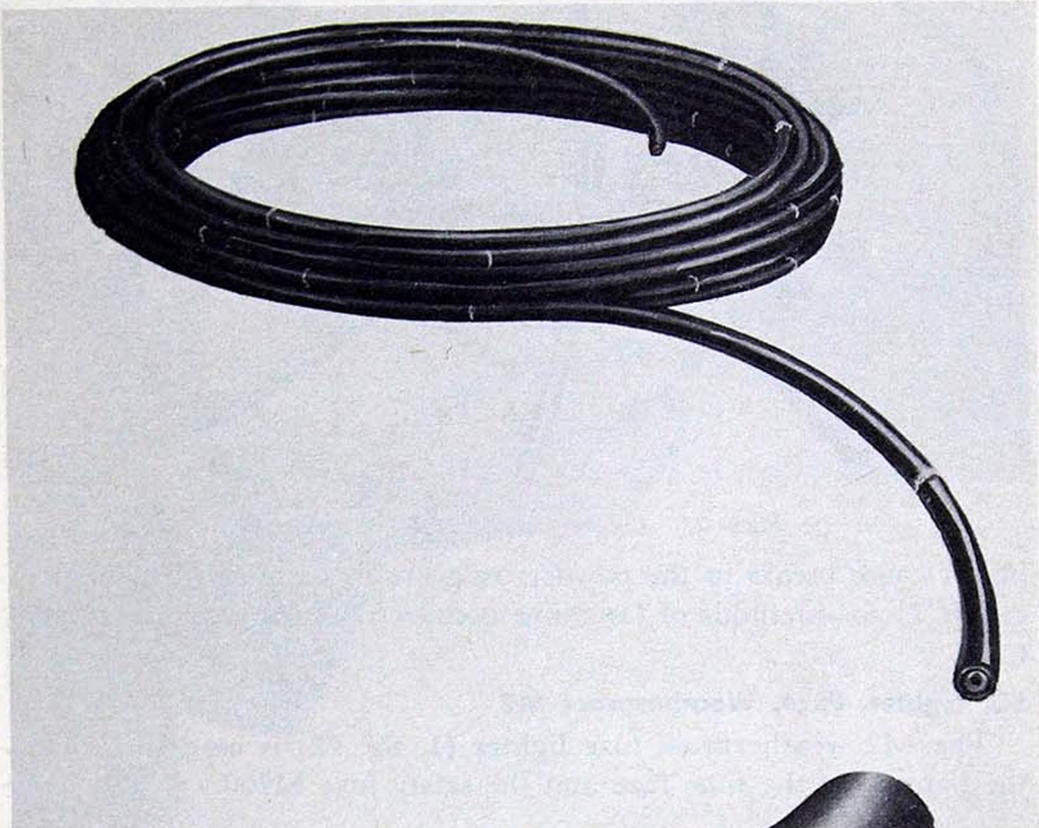
d. Packaging. Time fuze and safety fuze M700 are issued in 50-foot rolls. Two 50-foot rolls, one nested inside the other, are packed together.

e. Storage and Handling. Time fuze and safety fuze M700 should be stored in a cool, dry place, free from oils, paints, gasoline, kerosene, and similar distillates and solvents. In handling time fuze and safety fuze M700 twists, kinks, or sharp bends which may crack the cover-



1 Blasting time fuze.

Figure 20. Fuzes.



2 Safety fuze M700.

Figure 20—Continued.

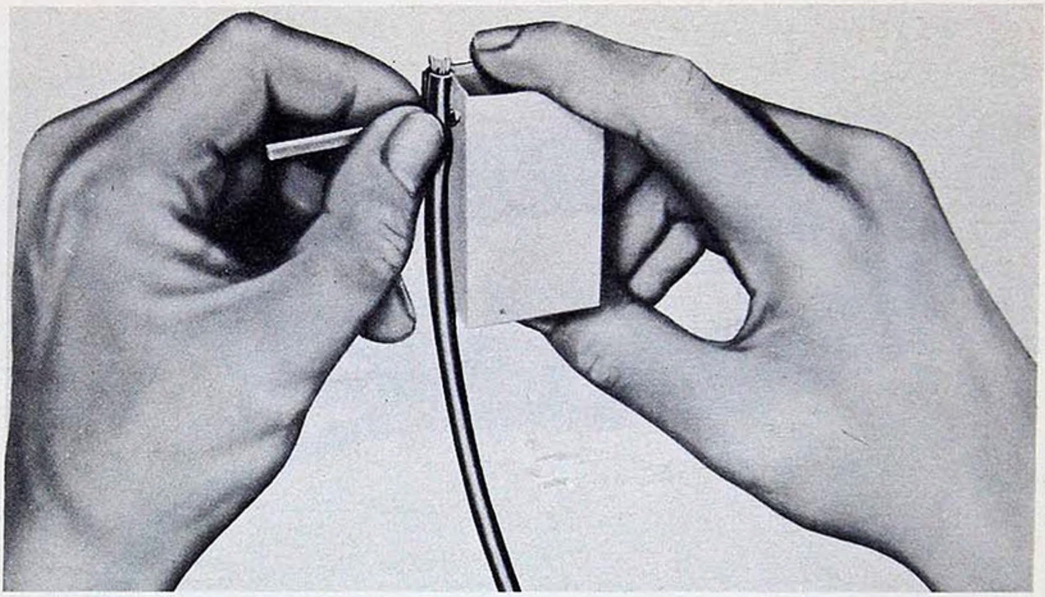
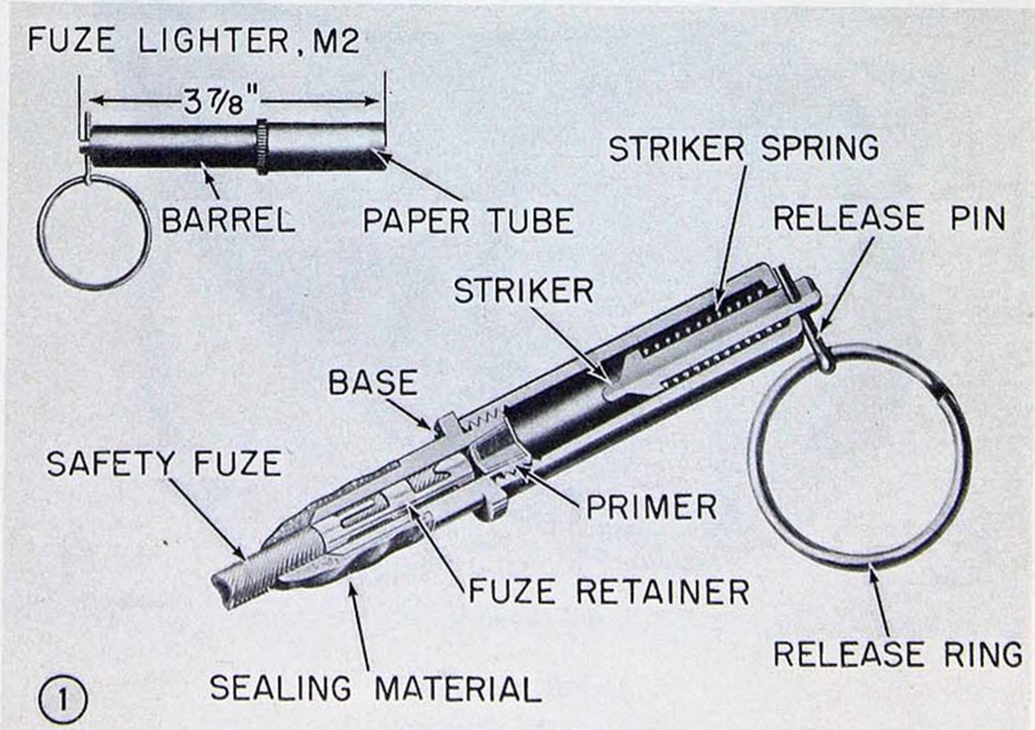


Figure 21. Lighting safety fuze M700 with match.

ing or cause breaks in the powder train are to be avoided. See paragraph 71 for methods of fastening nonelectric caps to time or safety fuze.

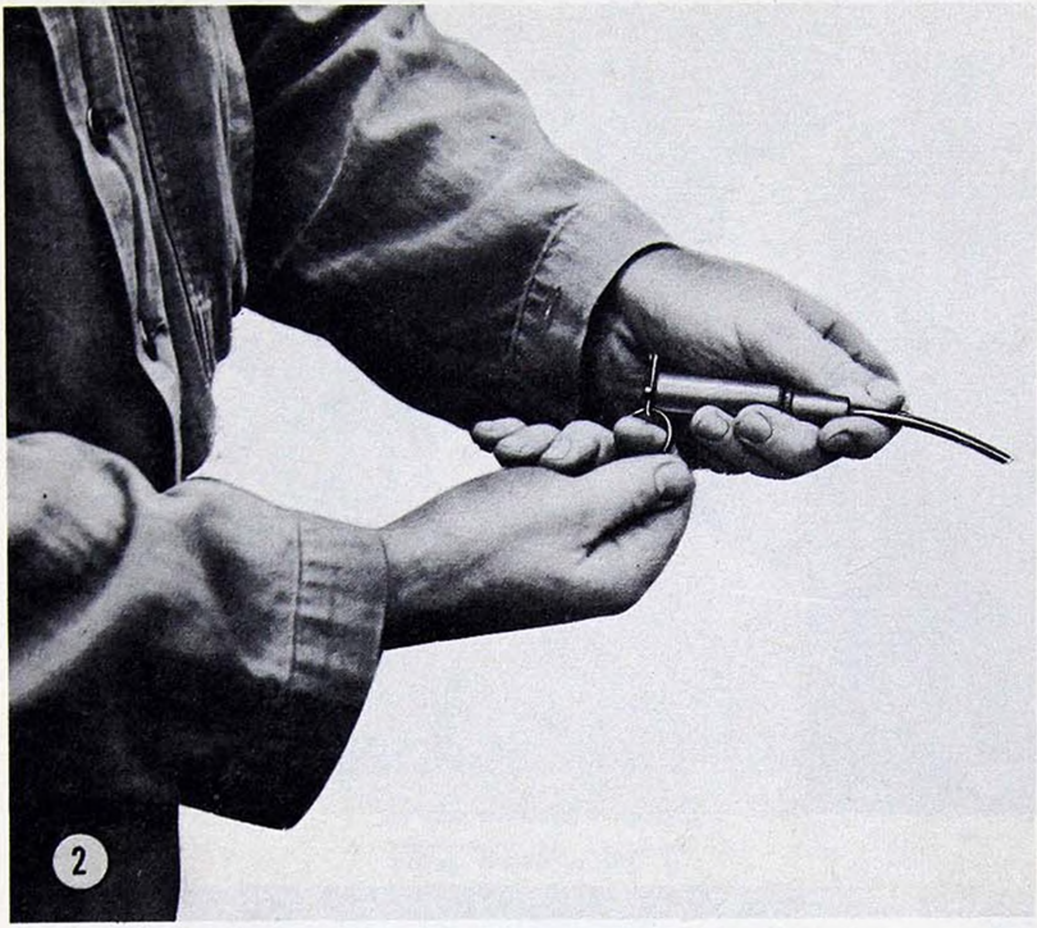
50. Lighter, Fuze, Weatherproof M2

The M2 weatherproof fuze lighter (1, fig. 22) is used to facilitate the lighting of the time fuze and the safety fuze M700. It will ignite



1 Fuze lighter.

Figure 22. M2 weatherproof fuze lighter.



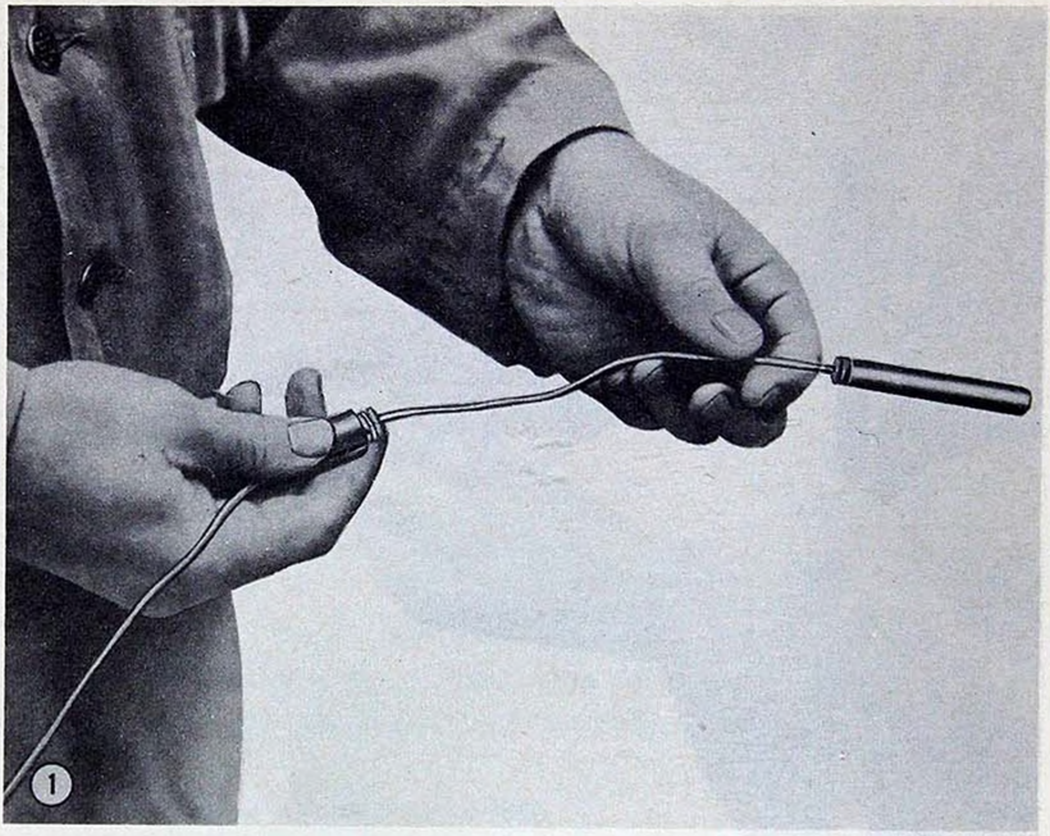
2 Pulling pin.

Figure 22—Continued.

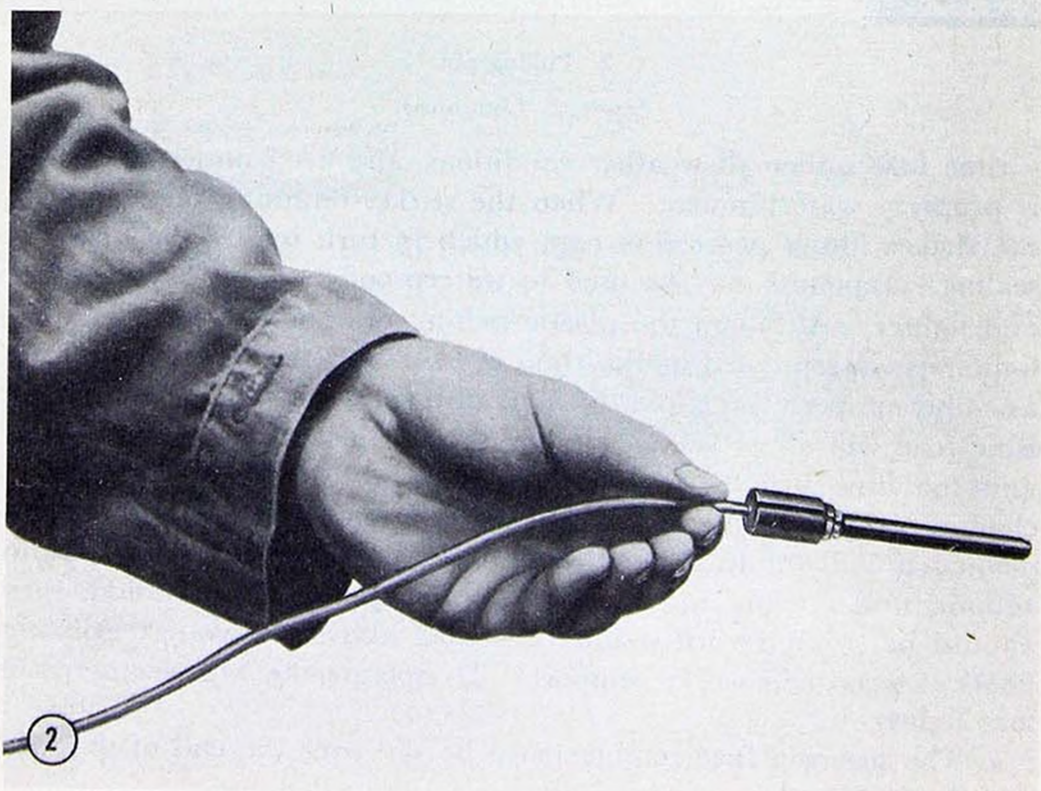
a time fuze under all weather conditions, and even under water if it is properly waterproofed. When the striker-retaining pin is pulled, the striker hits a percussion cap, which in turn ignites the fuze. A sealing compound may be used to waterproof the joint between fuze and lighter. Although the plastic sealing compound issued with the lighter is waterproofed at the time of issue and the nonelectric firing assembly properly prepared, a slight disturbance of the lighter on the time fuze will allow water to enter at the union between the lighter and the time fuze when installed under water. When underwater charges are placed utilizing a nonelectric firing system, they should be detonated with the least practicable delay. When such charges are to remain under water for a period of time prior to detonation, they should be primed with detonating cord above the water, utilizing floats of wood or cork for support. To operate the M2 weatherproof fuze lighter—

a. The pronged fuze retainer is to be slid over the end of the fuze and firmly seated.

b. The joint between the fuze and the lighter is to be waterproofed, if necessary, by applying sealing compound.



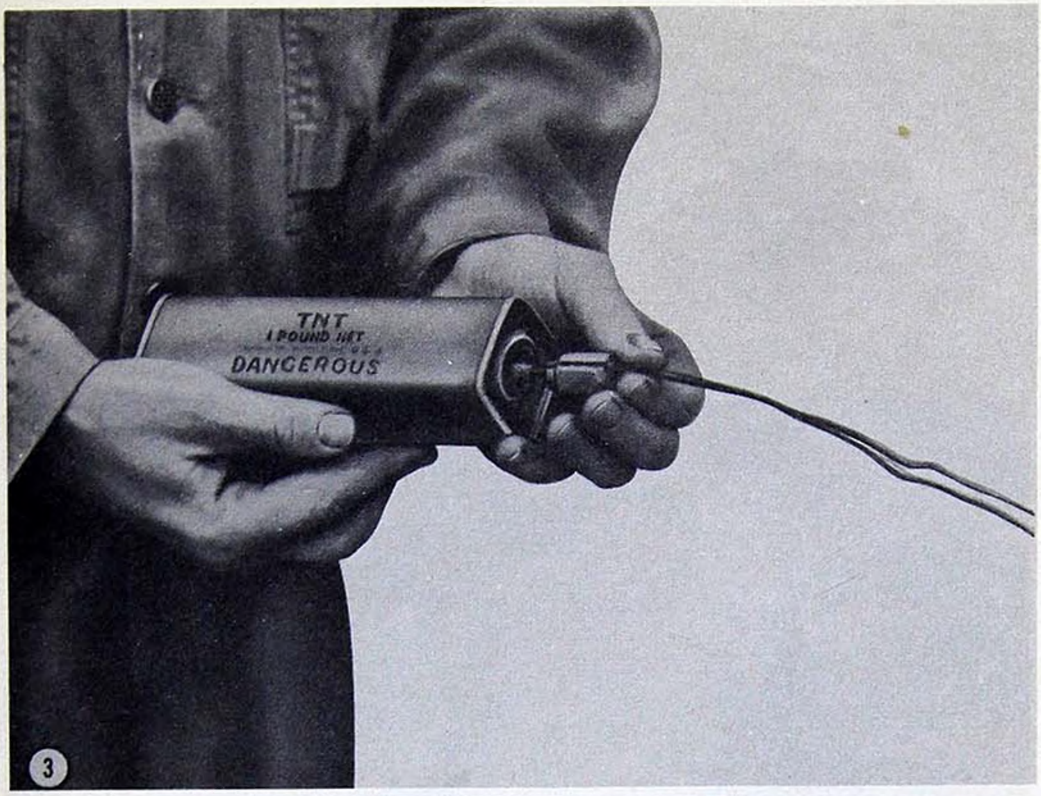
1 Placing adapter on wire.



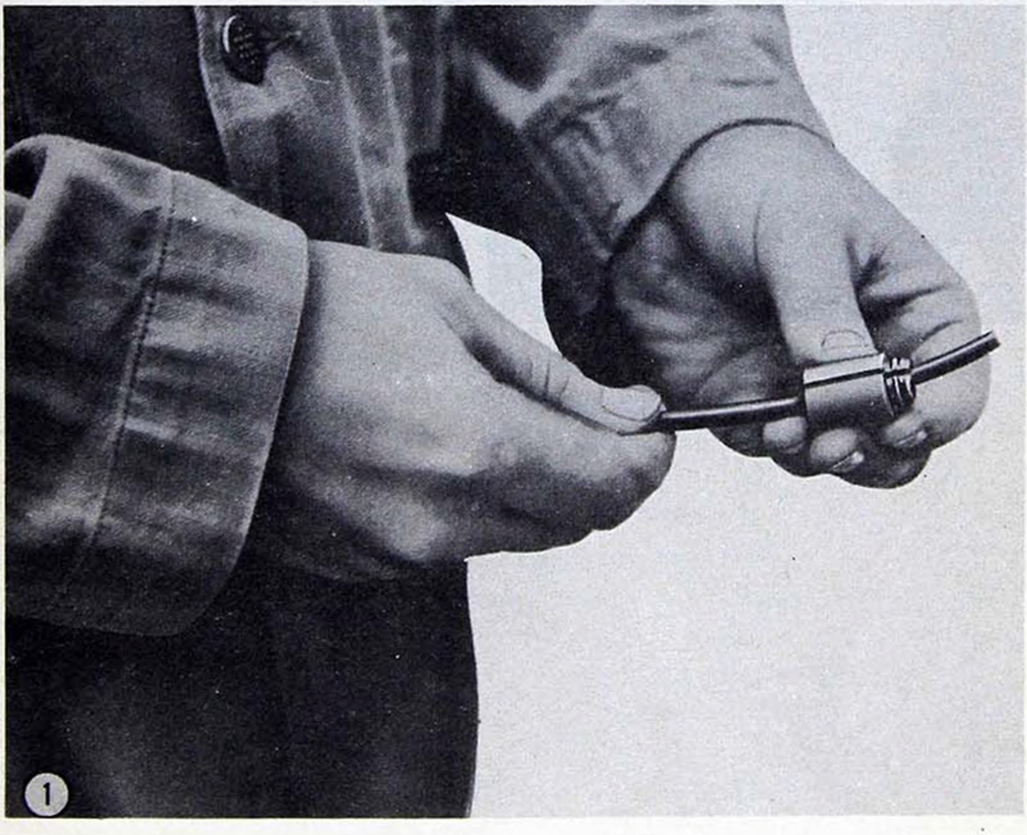
2 Sliding in place.

A—With electric cap

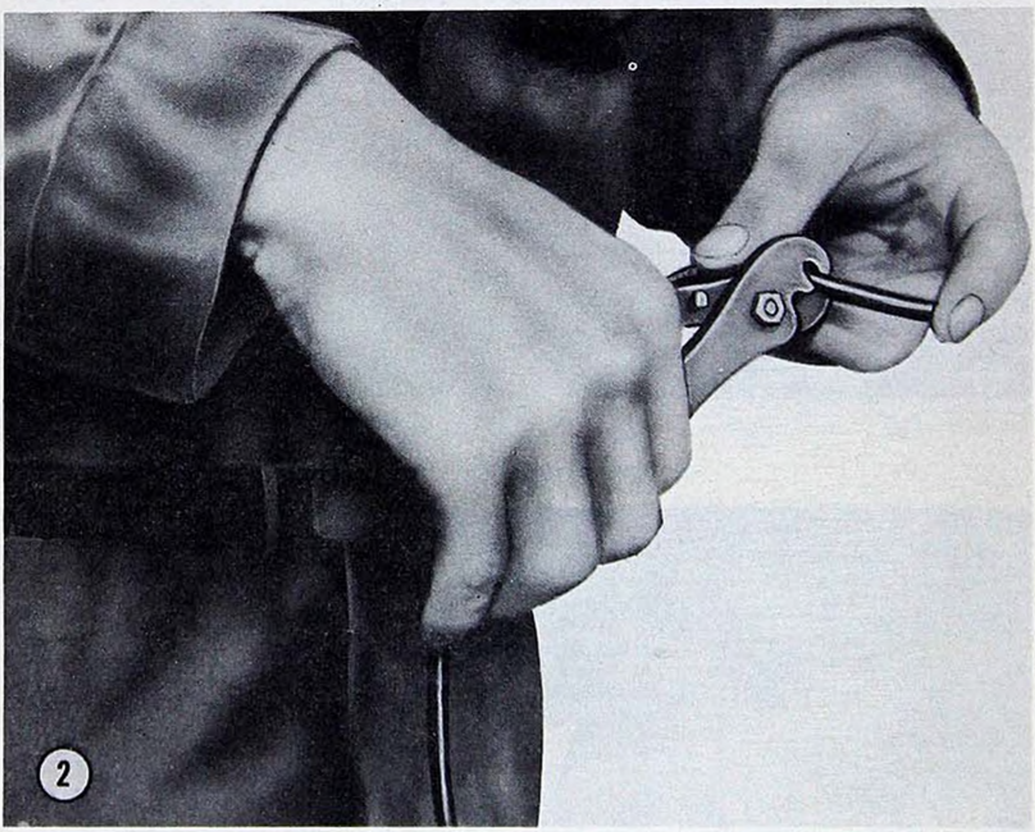
Figure 23. Methods of installing and using priming adapters.



3 Inserting in threaded cap well.
A—With electric cap—Continued.

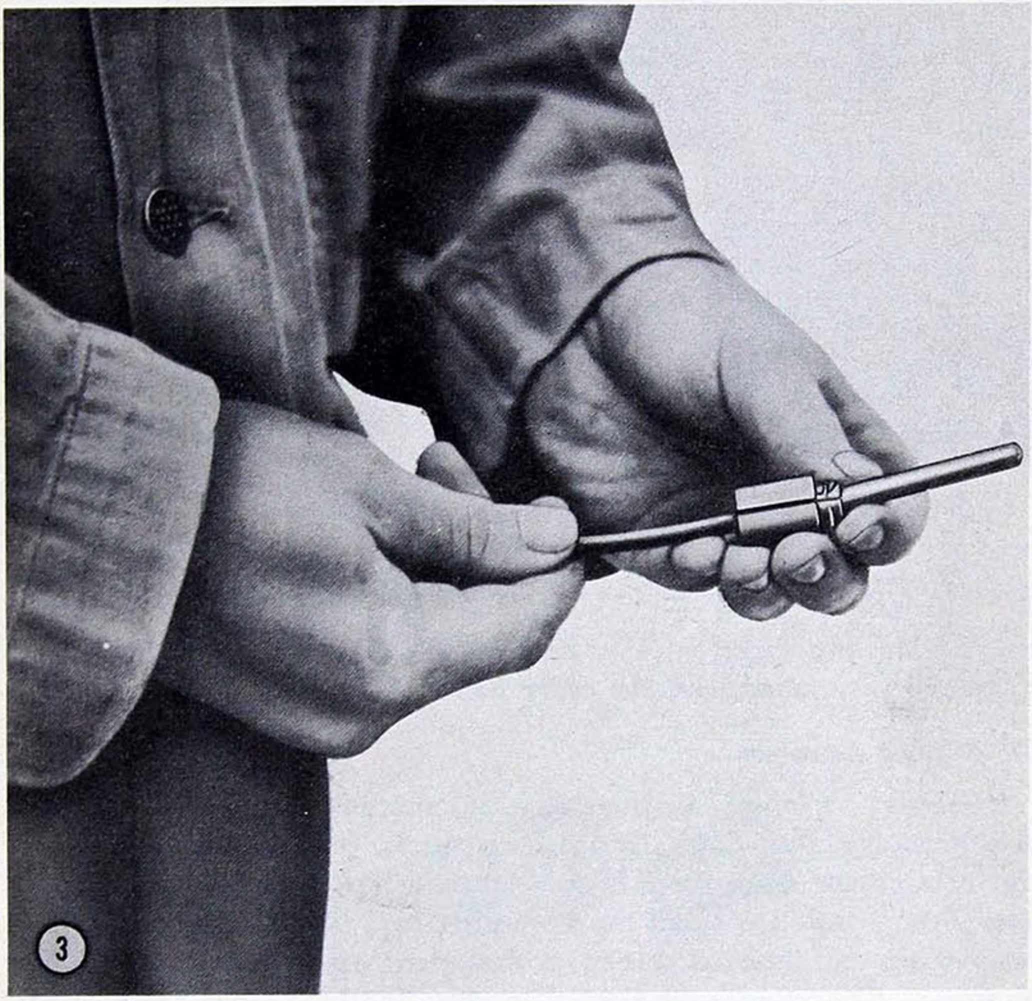


1 Placing adapter on time fuze.
B—With nonelectric cap.
Figure 23—Continued.



2 Crimping cap on time fuze.
B—With nonelectric cap—Continued.

Figure 23—Continued.



3 Sliding in place.
B—With nonelectric cap—Continued.

Figure 23—Continued.

4 Inserting in threaded cap well.
B—With nonelectric cap—Continued.

Figure 23—Continued.

c. To fire, the barrel is to be held in one hand, and the release ring on release pin pulled with the other hand (2, fig. 22).

51. Priming Adapters

a. General. Priming adapters (fig. 23) simplify the priming of military explosives that have threaded cap wells. A shoulder inside one end is large enough to permit time blasting fuze or detonating cord to pass through but too small for a blasting cap. The other end of the adapter fits the internal thread of threaded cap wells in military explosives. The adapter is slotted longitudinally so that wires of an electric blasting cap can be inserted easily and quickly.

b. Use.

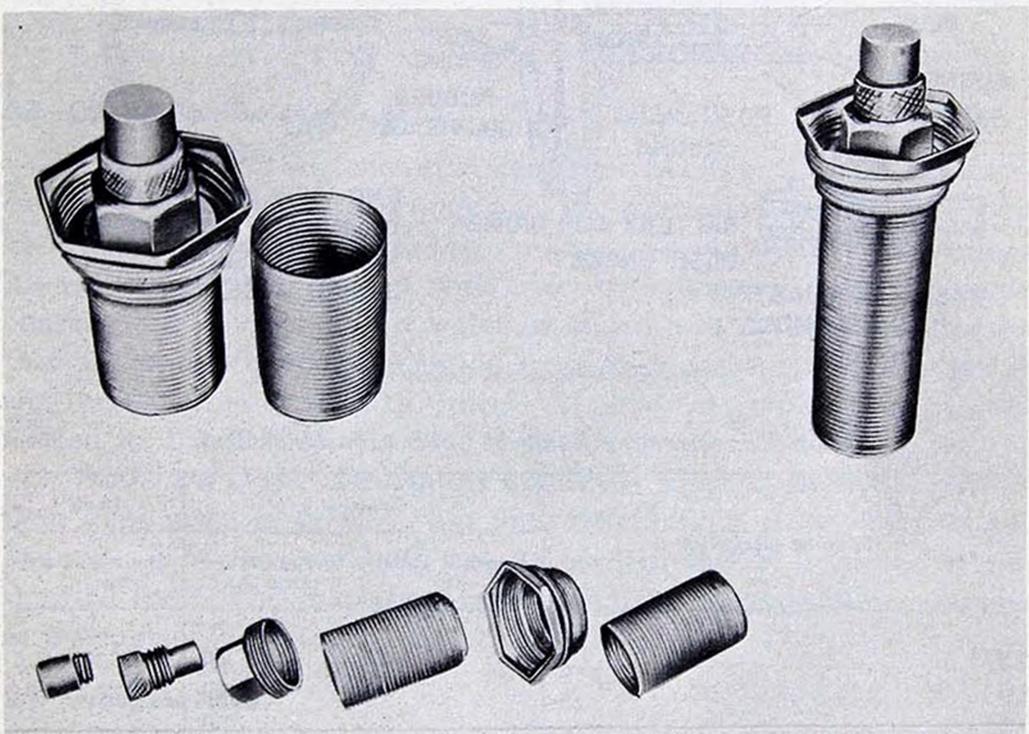
(1) *With electric blasting cap.* Cap wires of the electric cap are to be passed through slot of priming adapter. The cap is then pulled into the adapter. The cap is inserted into the cap well of the explosive and the adapter is screwed into the well.

(2) *With nonelectric blasting safety fuze M700 or time blasting fuze.* The end of the fuze is passed through the adapter and the nonelectric blasting cap is crimped to the fuze. The cap is pulled into the adapter and the cap is inserted into the cap well of the explosive. The adapter is screwed into place.

(3) *With detonating cord.* Six inches of cord are cut off from the running end of the spool of detonating cord and discarded. The same methods (*b*(1) and (2) above) that are used for non-electric caps and time-blasting fuze are used for detonating cord. Detonating cord alone in a cap well is not sufficiently powerful to insure detonation of military explosives. One special nonelectric or electric blasting cap contains as much explosive force in one end as is contained in approximately 6 inches of detonating cord.

52. Destructor, High Explosive, Universal M10

a. General. The universal high-explosive destructor M10 (fig. 24) is a high-explosive charge initiated by means of blasting caps or mine activators and standard firing devices. The booster cups contain tetryl



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. Destructor, high explosive, universal, M10.

pellets, high explosive. It is used in preparing loaded projectiles and bombs as improvised demolition charges, and the destructor is also used to destroy abandoned ammunition.

b. Safety Precautions. Safety distance requirements for preparation of primers and demolition charges as set forth in TM 9–1900 are to be observed when preparing the universal destructor M10 for use.

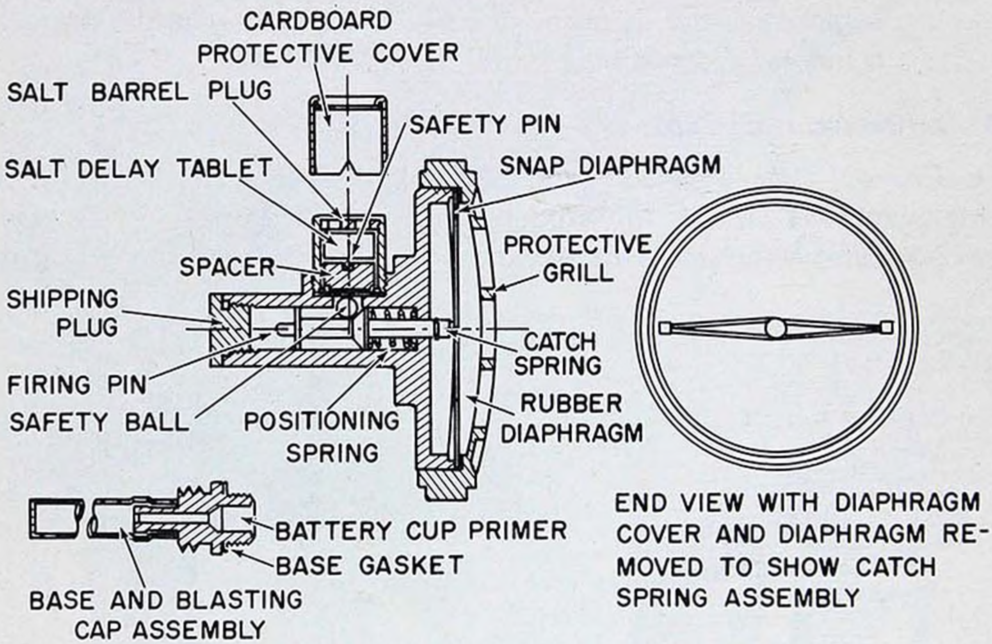


Figure 25. Concussion detonator, M1.

Table V. Operating Range of Concussion Detonators

Initiating charge (lb)	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	

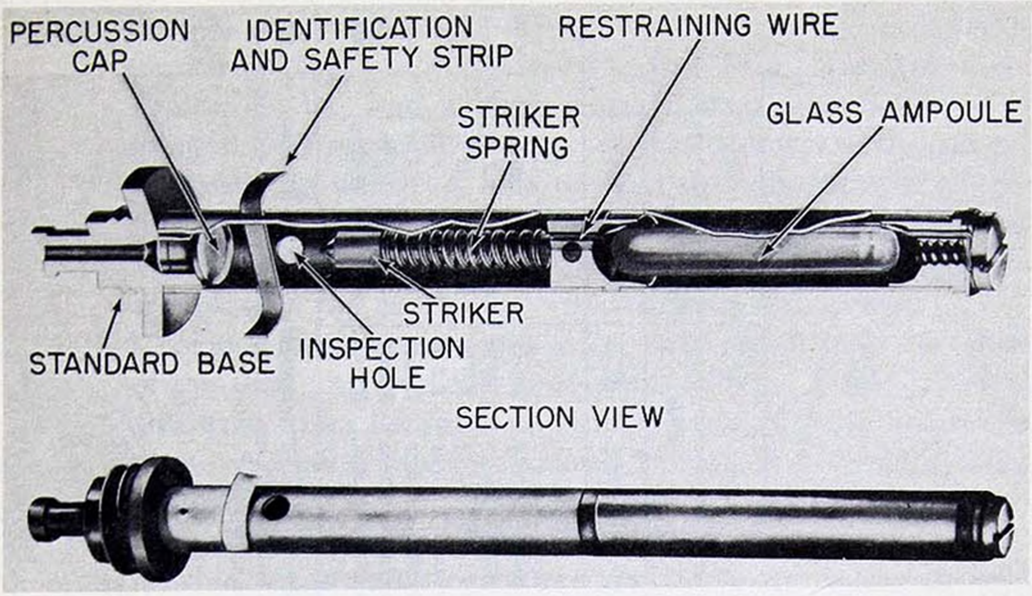


Figure 26. Firing device, delay type M1.

53. Concussion Detonator M1

a. Description. The concussion detonator M1 (fig. 25) is a mechanical firing device which is actuated by the concussion wave of a nearby blast. It can be used to fire several charges simultaneously without interconnecting the charges with wire or detonating cord. A single charge fired in any way, in water or in air, will detonate all charges that are equipped with concussion detonators and are within range of the main charge or of each other. Methods of employment are described in TM 9–1946.

b. Ranges and Depth. Detonators frequently function at ranges greater than those given in table V, but their reliability at those ranges is not assured. The device should not be used in surf at a greater depth than 15 feet. The snap diaphragm functions by hydrostatic pressure at a depth of 25 feet.

54. Firing Devices

a. General. Firing devices are of two general types, the tubular type and the box type. The tubular type firing devices consist of a head, case, and primed coupling base and are activated by pressure or pull. The box type consists of a rectangular steel body and primed coupling base and is actuated by release of pressure. These firing devices may be used on demolition blocks or explosive charges.

b. Firing Device, Delay Type M1.

(1) The M1 delay type firing device (fig. 26) gives a time delay of from 3 minutes to 23 days depending on the model and the prevailing temperature. Because the time delay interval of these firing devices is not exact, they are not to be used if accurate timing is required.

Table VI. Temperature Correction Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	t° F.	Black		Red		White		Green		Yellow		Blue		t° C.
		OM	ST	OM	ST	OM	ST	OM	ST	OM	ST	OM	ST	
1	−25	----------	----------	8.5 hr	3.3 hr	3 dy	1.3 dy	----------	----------	----------	----------	----------	----------	−32
2	0	8 hr	2.5 hr	45 min	20 min	17.5 hr	8 hr	2.6 dy	1.2 dy	8.5 dy	3.8 dy	23 dy	10 dy	−18
3	+25	36 min	16 min	25 min	11 min	5.5 hr	2.5 hr	17 hr	8 hr	2.0 dy	20 hr	5.0 dy	2.2 dy	−4
4	+50	15 min	7 min	17 min	8 min	2 hr	55 min	6 hr	2.7 hr	14 hr	6.0 hr	1.3 dy	14 hr	+10
5	+75	9 min	4 min	15 min	7 min	1 hr	27 min	2.5 hr	70 min	5.5 hr	2.5 hr	11.5 hr	5 hr	+24
6	+100	5 min	2.0 min	8 min	3.5 min	32 min	14 min	70 min	30 min	2.5 hr	65 min	5.2 hr	2.3 hr	+38
7	+125	4 min	1.5 min	5 min	2 min	20 min	9 min	35 min	15 min	80 min	36 min	2.5 hr	1.1 hr	+52
8	+150	3 min	1 min	4 min	1.5 min	15 min	6 min	20 min	9 min	46 min	21 min	80 min	36 min	+66

OM—When two pencils are used in the same charge, the OM is the most likely timing. When only a single pencil is used, the value should be increased by about 15 percent.

ST—The ST is a reasonably safe time. Timings shorter than the ST should not occur more often than once in a thousand trials. Red pencils should not be used below 0° F., nor black pencils below 25° F.

(2) The M1 delay type firing device consists of a tube containing percussion cap, a spring-loaded striker held cocked by a restraining wire, and a glass ampule 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 if the striker has been released prematurely. When the ampule is crushed, the corrosive solution dissolves a portion of the restraining wire, releasing the striker.

(3) A colored identification and safety strip fits through the sides of the tube and prevents premature firing. Table VI gives the delay time for fuzes of each color at different temperatures. A similar table is included in each box with the firing devices.

(4) To use M1 delay type firing device—

(*a*) Table VI is to be consulted for tab color giving desired time delay at prevailing temperature.

(*b*) A firing device is selected with safety strip of tab color giving the desired time delay.

(*c*) A nail is inserted through the inspection hole to make certain, or visual inspection is made to make certain, that the striker has not been released.

(*d*) The portion containing the ampule is inspected to see that it has not been crushed.

(*e*) A nonelectric special blasting cap is crimped to the base of the firing device.

(*f*) The cap is inserted in the charge or, if detonating cord is used, the cap is taped to the cord.

(*g*) The ampule is crushed by pressing the tube containing it with your fingers.

(*h*) Look through the inspection hole to see if the striker has fallen. If the striker has fallen, the firing device is discarded without removing its safety strip.

(*i*) If the striker has not fallen the identification and safety strip are withdrawn.

(*j*) Retire to a safe distance.

c. Mine and Boobytrap Firing Device. Descriptions and uses of standard fuzes and firing devices to detonate mines and boobytraps are given in FM 5-31, TM 9-1940, and TM 9-1946. The firing devices include general types as follows:

(1) *Pull firing devices.* The M1 pull firing device fires when a trip wire is pulled.

(2) *Pressure firing device.* The M1A1 pressure firing device fires when pressure is applied to it.

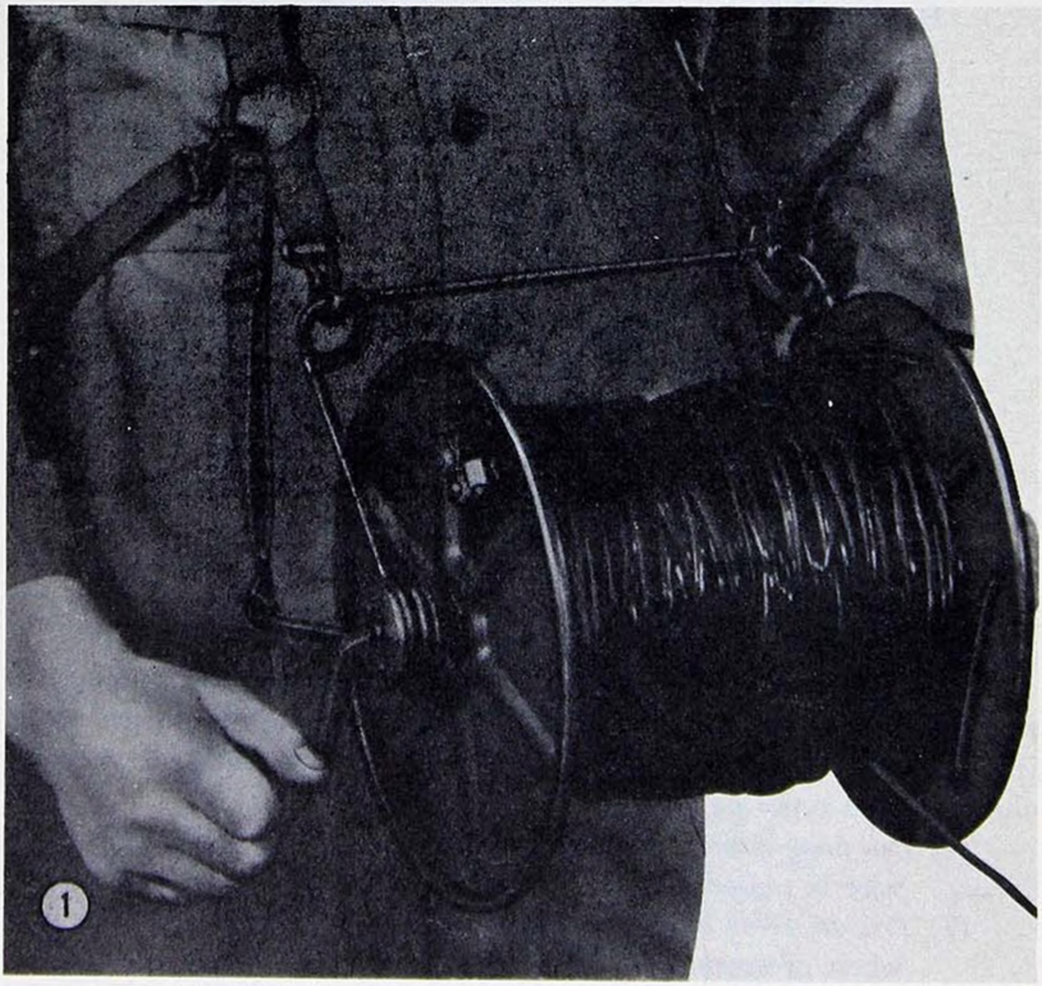
(3) *Pressure-release firing device.* The M5 pressure-release firing device fires when pressure is released from it.

(4) *Tension-release firing device.* The M1 release firing device fires when tension on a taut trip wire is released.

(5) *Combination firing device.* The M3 pull-release firing device fires whenever a taut trip wire 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.

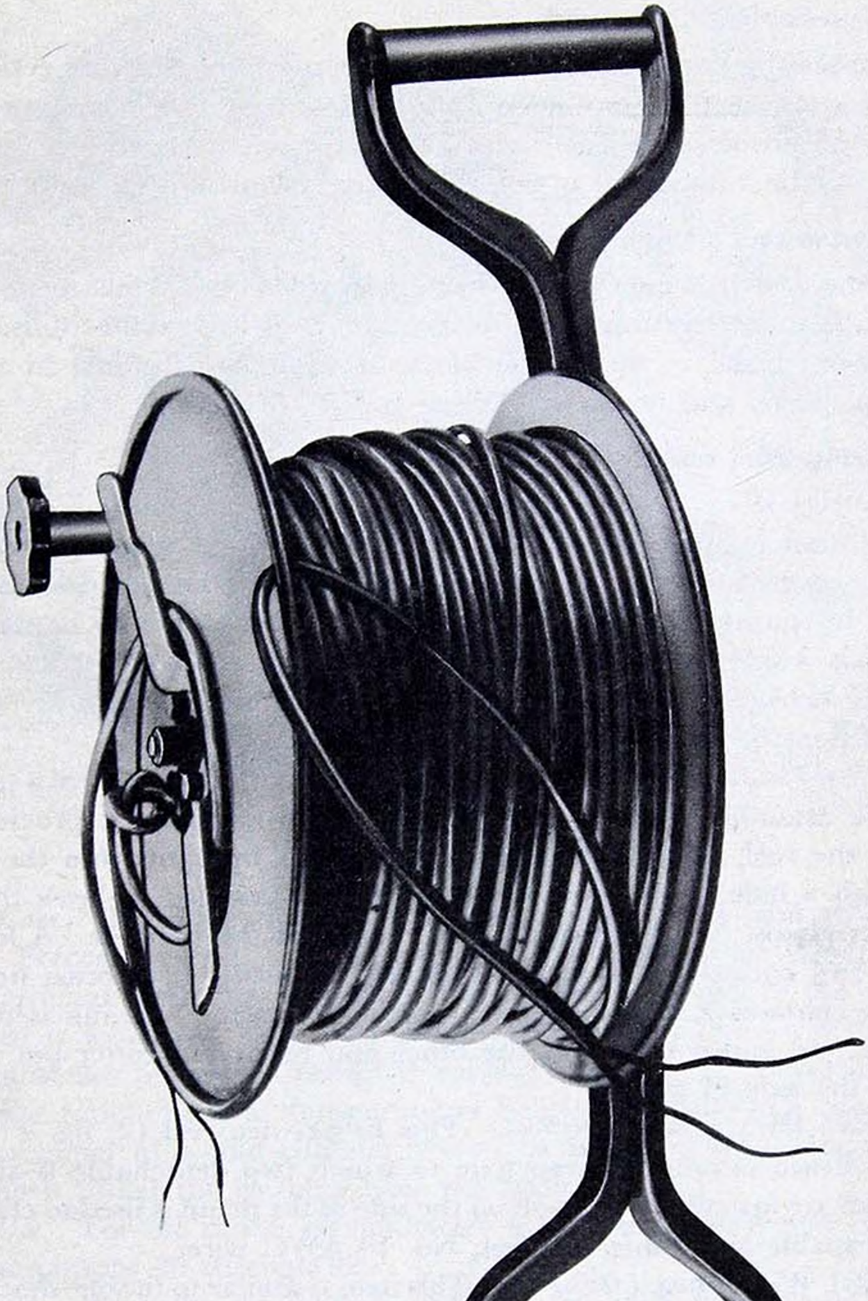
55. Adhesive Compound

Adhesive compound is a sticky, puttylike substance for attaching charges to vertical or overhead flat surfaces. It is useful in holding charges while tying them in place or, under some conditions, in holding charges without tying. Charges can be held in place 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. It will not adhere satisfactorily to dirty, wet, or oily surfaces. It is softened by water and becomes useless when wet. Ad-



1 Reel unit RL 39A.

Figure 27. Firing wire reels.



2

2 Firing wire reel.

Figure 27—Continued.

hesive compound becomes stiff and hard at subzero temperatures and loses its adhesive quality.

56. Cap-Sealing Compound

Cap-sealing compound is used to moistureproof the connection between a nonelectric blasting cap and a time fuze and to moistureproof dynamite primers. It does not make a permanent waterproof seal and must not be submerged unless the charge is to be fired immediately.

57. Twine and Friction Tape

Twine and friction tape are included in demolition sets to tie blasting caps to detonating cord, to insulate electrical connections, to fix charges in place, to tie or tape blocks of explosives together in a compact package, and to fasten blasting caps to primers.

58. Firing Wire and Reel

a. Firing Wire. Firing wire, for electric firing of charges, is issued in 500-foot lengths of 2 conductor, No. 18 AWG plastic-covered or rubber-covered wire. The wire is carried on one of the reels described below. In setting off a charge, 1 or more reels of wire may be required to reach a safe distance. Single-conductor No. 20 AWG annunciator wire is issued for making connections between blasting caps or making connections between blasting caps and firing wire.

b. Reel Unit RL 39A. Reel unit RL 39A (1, fig. 27) consists of a spool, a handle assembly, a crank, and an axle. Two straps are provided to carry the reel. The fixed end of the wire is brought from the spool through a hole in the side of the drum and fastened to brass thumb-nut terminals. Two U-shaped steel rods form the handles. A loop at each end encircles a bearing assembly, consisting of a brass housing which contains a steel center to receive the axle. A crank is riveted to one end and a hole near the other end receives a cotter pin which holds the axle in place.

c. Reel, Wire, Firing, 500-Foot. This firing-wire reel (2, fig. 27) is a metal drum mounted on an axle to which two detachable D-shaped handles are fastened. A knob on the side of the drum is used to crank it. It is capable of holding 500 feet, No. 18 AWG wire.

d. Reel, Wire, Firing, 1,000-Foot. This item is similar to the one described in *c* above except that it has a capacity of 1,000 feet of firing wire.

59. Galvanometer

a. Description. The galvanometer (fig. 28) is an instrument to test electric firing-wire circuits. It contains an electromagnet, a small special silver-chloride dry cell, and a scale and indicator needle. When the two external terminals are joined by a closed circuit, the flow of current from the dry cell causes the needle to move across the scale. The amount of deflection depends upon the amount of resistance in the closed circuit and on the strength of the cell.

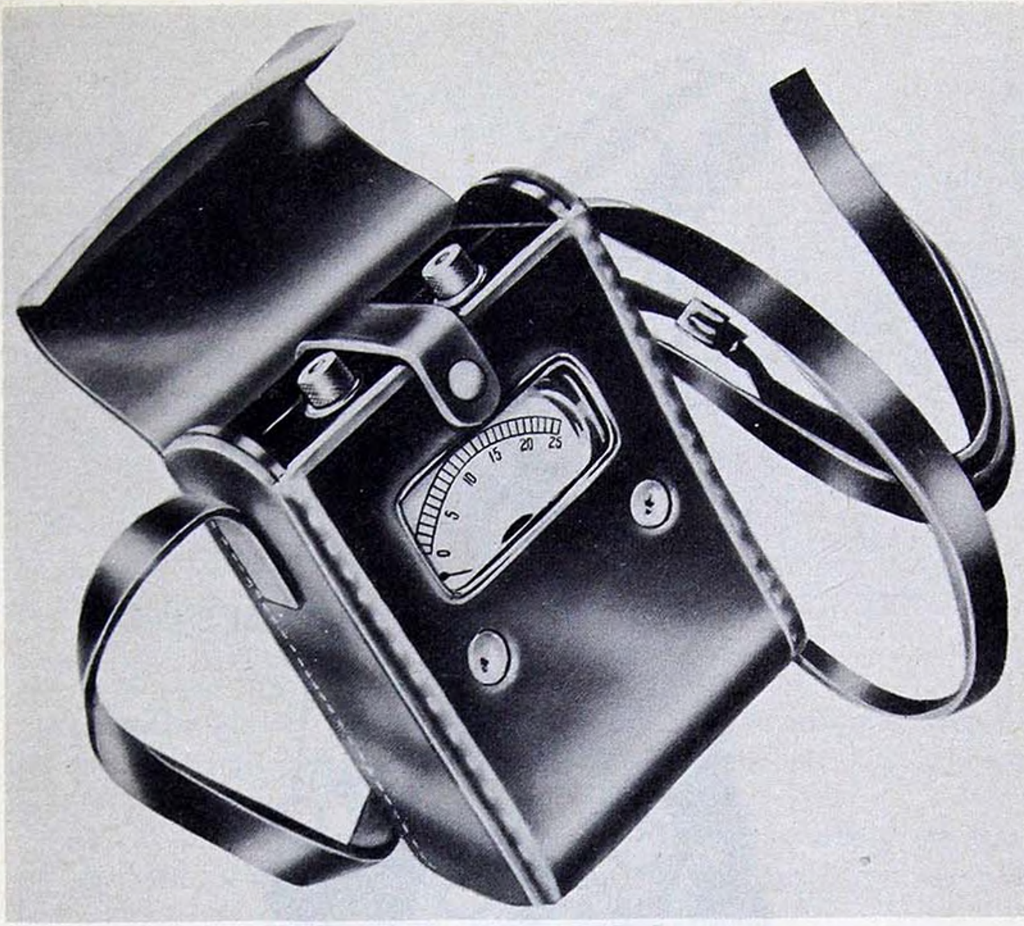


Figure 28. Galvanometer.

b. Care. The galvanometer must be handled with care and kept dry. Before using, it is tested 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. The galvanometer is delicate and must not be opened except to replace a weak cell. Dry cells tend to cease functioning at temperatures below 0° F. When using the galvanometer in a cold climate, it is to be protected from freezing by placing it under the clothing near the body.

c. Use. For use of the galvanometer to test firing wires and circuits, see paragraphs 90 through 92.

Caution: Only the special silver chloride dry cell battery BA 245/U is to be used in the galvanometer. Other cells will sometimes detonate blasting caps.

60. Blasting Machines

The blasting machine is a small electric generator for firing electric caps. Blasting machines are impulse type generators, that is, they fire instantaneously when the handle reaches the end of its travel, and hence are not dependable for firing parallel circuits (par. 87*b*). Information on blasting machines used for military purposes follows.

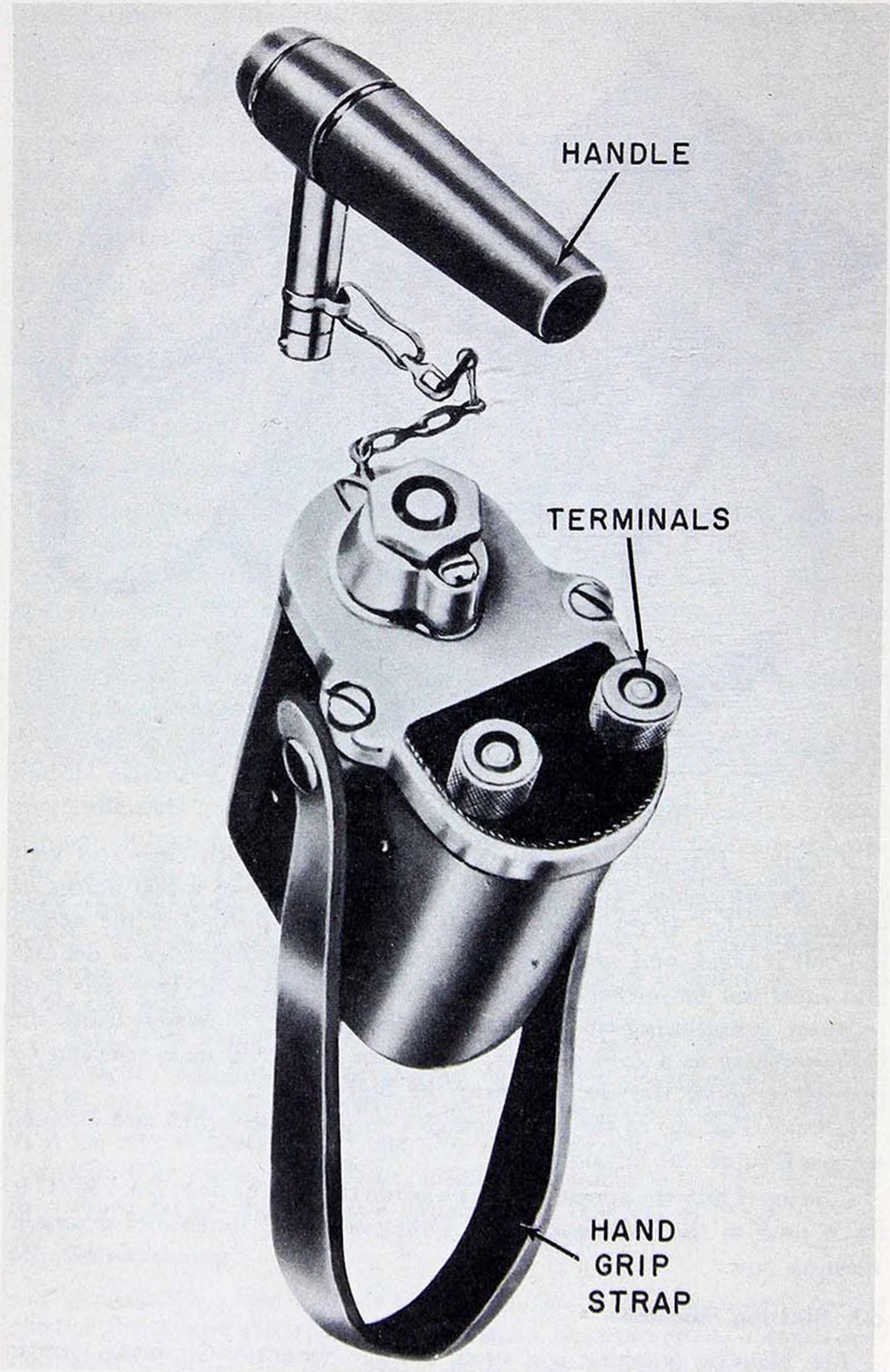


Figure 29. 10-cap blasting machine.

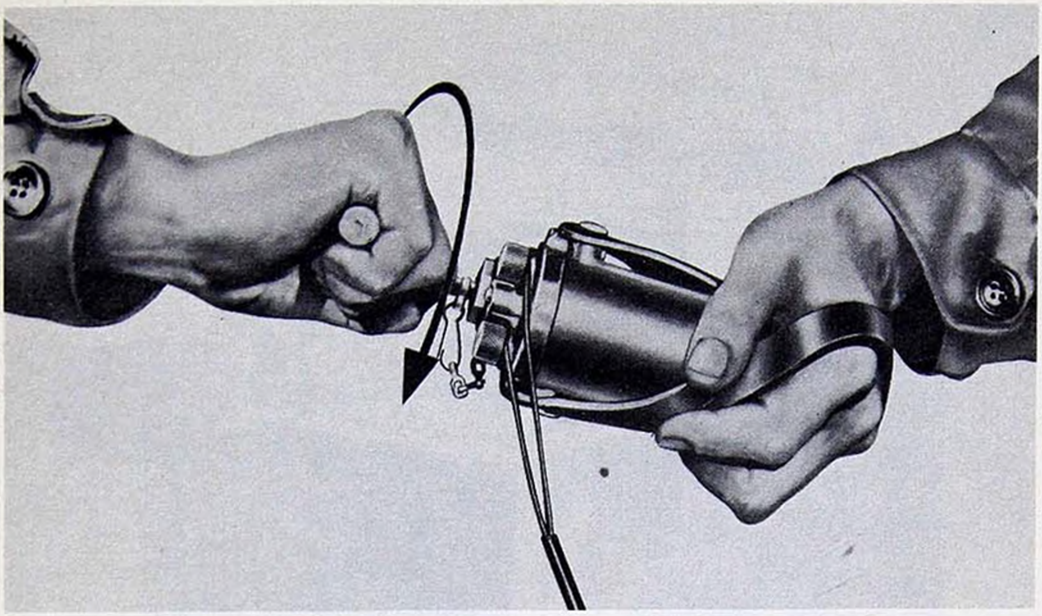


Figure 30. Method of using 10-cap blasting machine.

a. Ten-Cap Blasting Machine. The 10-cap blasting machine (fig. 29) can fire 10 electric blasting caps connected in series. It is operated as follows:

(1) The machine is checked to see that it is working properly. Before the firing wires are attached, the machine is operated several times so that it will work smoothly.

(2) The lead wires are tightly fastened to the terminals of the blasting machine.

(3) The handle is inserted.

(4) The left hand is inserted through the strap and the bottom of the machine is grasped firmly with the back of the right hand toward you, as shown in figure 30.

(5) The handle is grasped and given a vigorous clockwise turn as far as possible.

b. Thirty-Cap Blasting Machine. The 30-cap blasting machine (fig. 31) is capable of firing 30 electric caps connected in series. It weighs about 20 pounds. It is operated as follows:

(1) The handle is raised to the top of its stroke.

(2) The handle is pushed down quickly, as far as it will go.

c. One-Hundred Cap Blasting Machine. The 100-cap blasting machine is similar to the 30-cap except for size and weight, and is operated in a similar manner. It is capable of firing 100 electric blasting caps connected in series.

d. Precautions When Connecting Blasting Machine. One individual is detailed to fire the circuit. The blasting machine should be connected to the firing circuit only by the person so detailed. This individual should carry the machine, or at least its handle, on his person at all times during any activities related to blasting. He should also be the

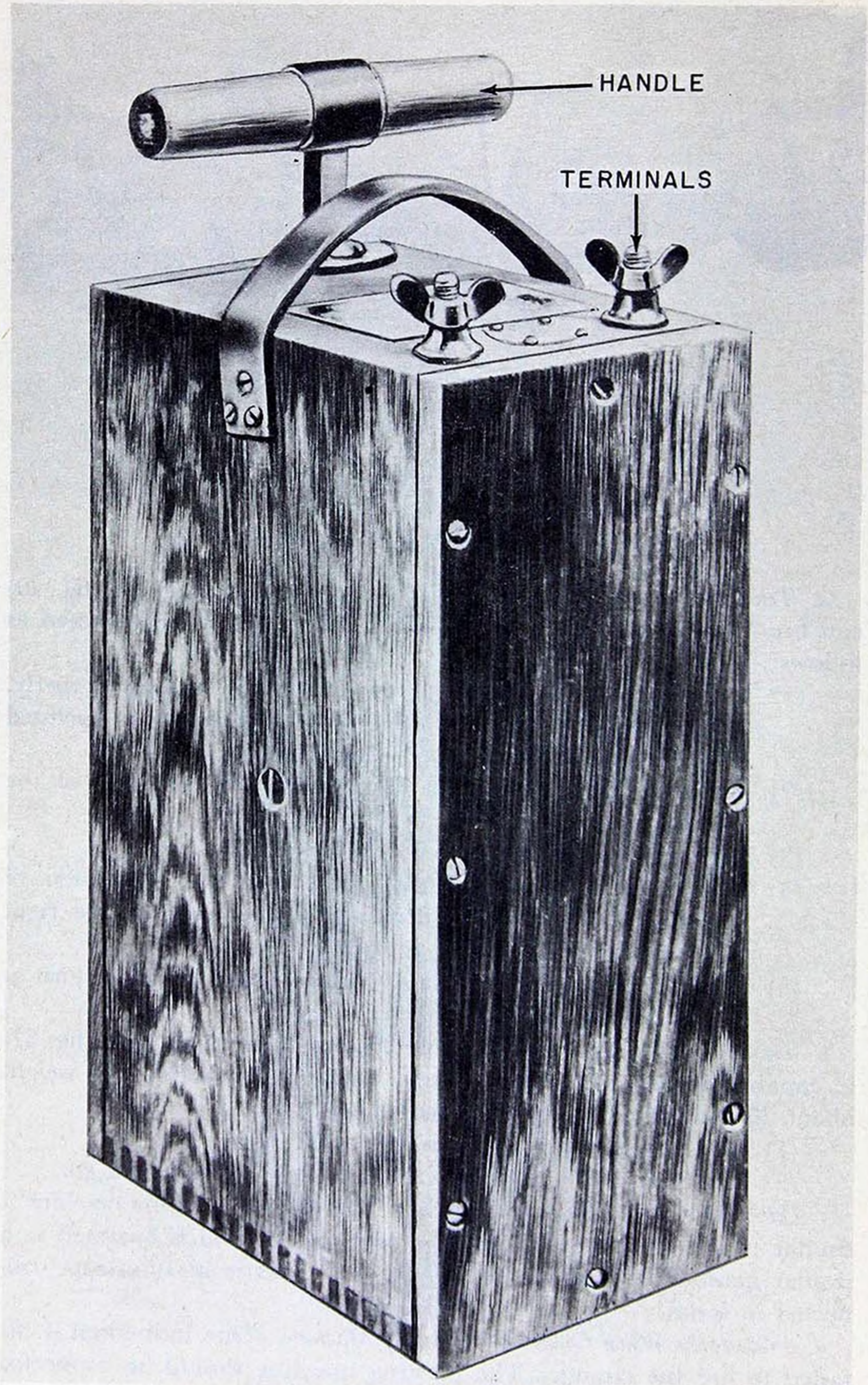


Figure 31. 30-cap blasting machine.

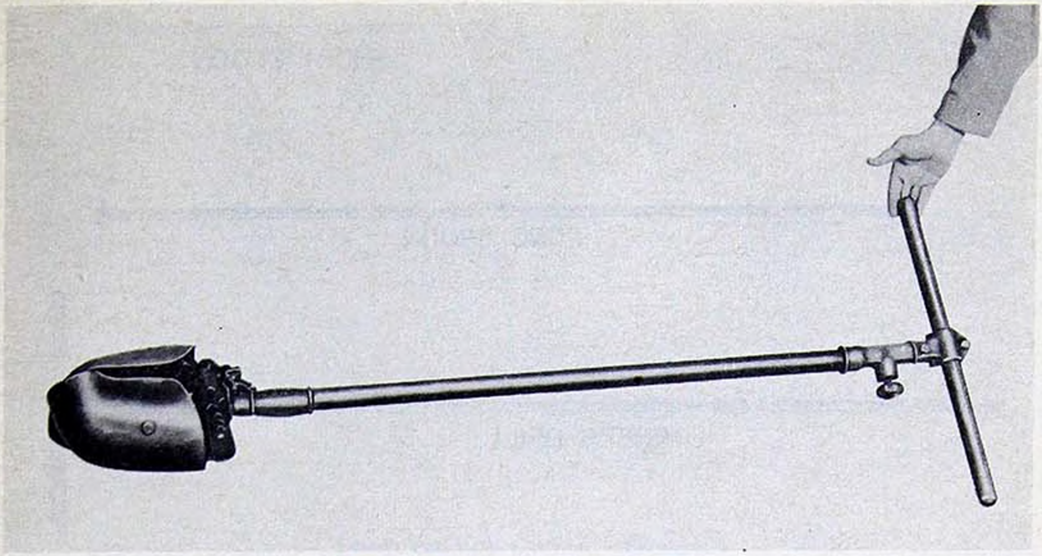


Figure 32. Post hole auger.

individual who either connects the blasting cap wires in the circuit or checks their connection by on-the-spot visual examination.

61. Charge Setting Equipment

a. Earth Augers. Earth augers are of two styles, hand-operated and motorized. They are used to bore holes in earth for placing cratering charges and bridge-abutment demolition charges. Boring speed depends upon the type of soil, being most rapid in light earth or loam. Earth augers perform satisfactorily in clay or light gravelly soil but cannot be used in soil containing large rocks.

(1) *Hand-operated auger.* The 10-inch post hole auger (fig. 32) is capable of boring a hole large enough for the 40-pound ammonium nitrate cratering charge and other charges of equal size. It has a telescoping extension handle which permits drilling holes as deep as 8 feet.

(2) *Motorized earth auger.* Motorized earth augers drill holes of 8-, 12-, 16-, or 20-inch diameter, up to 9½ feet deep.

b. Miner's Drill. The 2½-inch sectional-handled miner's drill shown in figure 33 may be used to bore holes for cratering charges and abutment demolition charges. In drilling with the 2½-inch miner's drill, water is poured down the borehole from time to time to soften the soil and make mud, which in turn acts as a lubricant. The spoil is removed from the borehole by periodically removing and cleaning the drill. Spoil not clinging to the drill is removed with a miner's spoon (fig. 33).

c. Pneumatic Tools. Pneumatic tools are useful in many types of demolition work.

(1) The rock drill is capable of drilling holes up to 2 inches in diameter in rock, concrete, or masonry. It is used for drill-

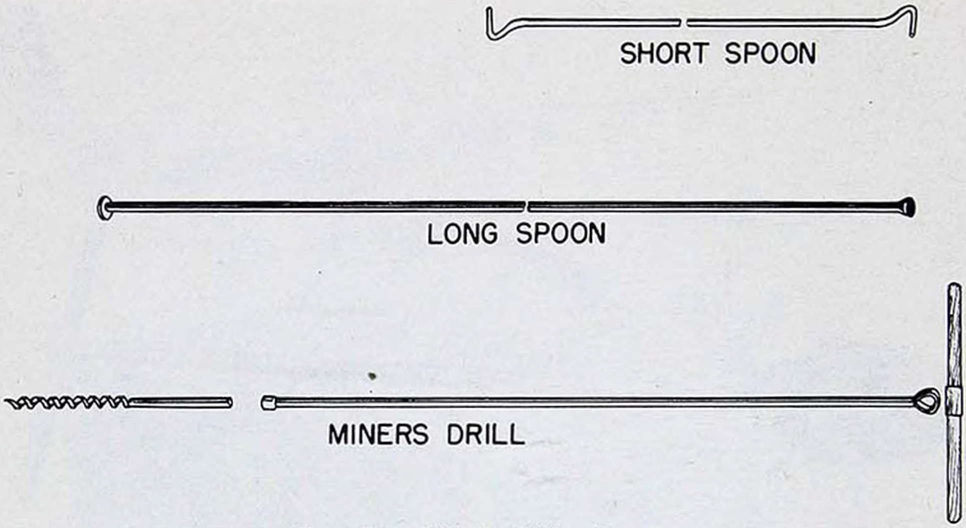


Figure 33. Miner's drill and spoons.

ing boreholes so that internal charges can be placed in these materials.

(2) The paving breaker is used to break the hard surface of roads before drilling boreholes for placing cratering charges.

(3) The wood-boring machine is used to drill boreholes in wood for placing internal charges.

d. Rivet-Punching, Powder-Actuated Driver.

(1) *Description.* This tool (fig. 34) is a powder-actuated riveting machine which owes its propellent action to the gases generated by a fired cartridge. It is hand-operated, air cooled, and feeds from a magazine which holds 10 fastener units. The tool is designed to be usable both on land and under water. The fastener unit, which is waterproofed, consists of three metal parts: the fastener, which has a sharp point and a coarsely knurled body to provide maximum holding power in light steel, softer metals, concrete, and heavy wood; the sabot, an annular threaded unit which screws onto the rear of the fastener to guide it in ejection, to act as a stop-shoulder, and to provide additional bearing on the material penetrated; and, the cartridge case, a specially-wadded caliber .38 shell case. Because of the difficulty of cocking the tool under water, a manual cocking device is provided for underwater use.

(2) *Use.* When the cartridge is fired, the fastener and attached sabot are propelled at high speed into the desired target, acting as a rivet for the attachment of charges or other objects. (Do not fire the powder actuated driver into explosive or immediately adjacent to exposed explosive.) This tool is universally useful for attaching charges to steel, concrete, and wooden obstacles. It is especially effective for underwater work, or where only limited working space is available for attachment of charges.

Figure 34. Rivet-punching, powder-actuated driver.

e. Cap Crimpers. The M2 cap crimper (fig. 35) is designed to squeeze the shell of the nonelectric blasting cap around a time fuze or detonating cord tightly enough to prevent it from being easily pulled off but not tightly enough to interfere with the burning of the powder train in the fuze or the detonation of the detonating cord. The M2 cap crimper crimps a water-resistant groove completely around the blasting cap. The lower portion of the jaws of the crimper is shaped and sharpened for cutting fuze and detonating cord. One leg of the handle is pointed. This pointed leg is used for punching holes in dynamite

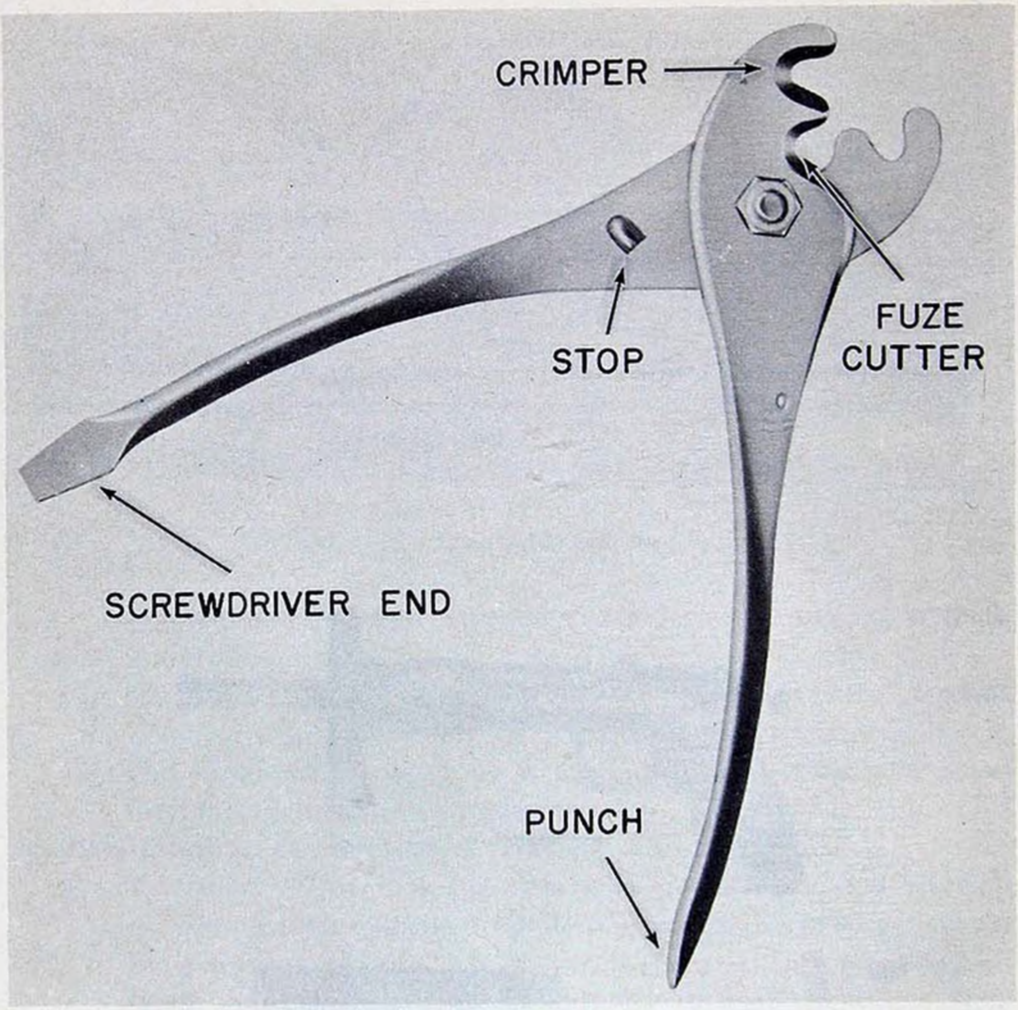


Figure 35. M2 cap crimper.

cartridges for easy insertion of blasting caps. The other leg has a screwdriver end. The cutting jaws must be kept clean and must be used only for cutting fuze or detonating cord. Cap crimpers are made of a soft, nonsparking metal, and therefore must not be used as pliers of any kind, because this would damage the working surface.

62. Demolition Charge Computing Tape

a. General. The charge computing demolition tape (fig. 36) is designed to provide a rapid method of calculating the weight of TNT (in pounds) required to accomplish specific demolition projects. It combines, in an abbreviated form, most of the formulas and tables contained in chapter 6.

b. Components. The tape assembly consists of two 6-foot, flexible steel, spring retractable tapes in metal housings. These housings are joined. The 2 tapes have a total of 5 sets of markings, while a rigid embossed scale is added to a mounting on 1 side of the joined housings. The tape scales consist of the following:

(1) *First tape (breaching and pressure scales).* The upper side of this

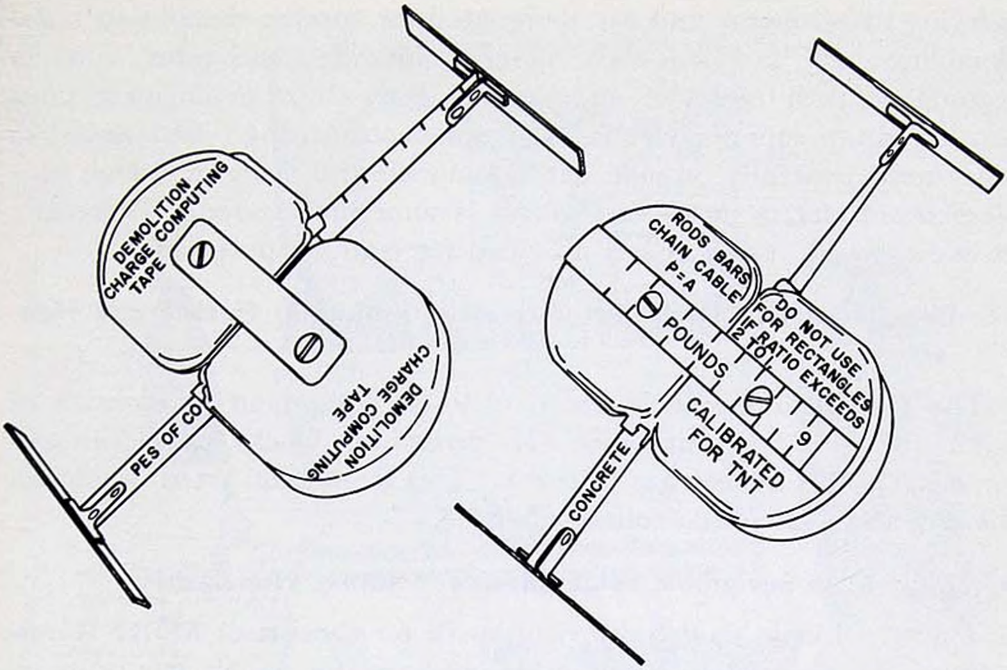


Figure 36. Charge computing demolition tape.

tape gives the pounds of TNT required for breaching concrete, masonry, timber, or earthen walls. It makes allowances for the tamping and placement of the charges. The weight of TNT required can be read directly to the right of the mark indicating the thickness of the wall or obstacle. The lower side of the tape provides information on breaching of concrete beams, roadways, and bridge spans. It is used to measure the thickness of the element and the charge can be read directly without getting the actual dimensions of the element to be breached or cut.

(2) *Second tape (steel and timber cutting scales).* This tape covers the requirements for cutting steel and timber construction members. One side gives the weight of TNT required for cutting timber both for internal and external placement. The reverse side consists of a rule to facilitate the calculation of the cross-sectional area of steel members with formula for cutting.

(3) *Bar and rod cutting scale.* This small scale on the exterior of the tape case is used to make calculations for the cutting of rods, bars, chains, and cables. The number of pounds of TNT required for cutting can then be read directly from the scale.

Section II. DEMOLITION SETS AND KITS

63. General

Demolition sets are composed of demolition explosive items, accessories, and tools. These sets have specially designed containers and carrying attachments and are designated for specific demolition tasks. Demolition sets are issued to engineer, infantry, and other units in accordance with tables of equipment. Sets issued to engineer units contain equipment for electric and nonelectric firing. Sets issued to other units generally provide only for nonelectric firing, although supplementary electric firing equipment is sometimes issued. There are, in addition, two types of sets provided for training purposes.

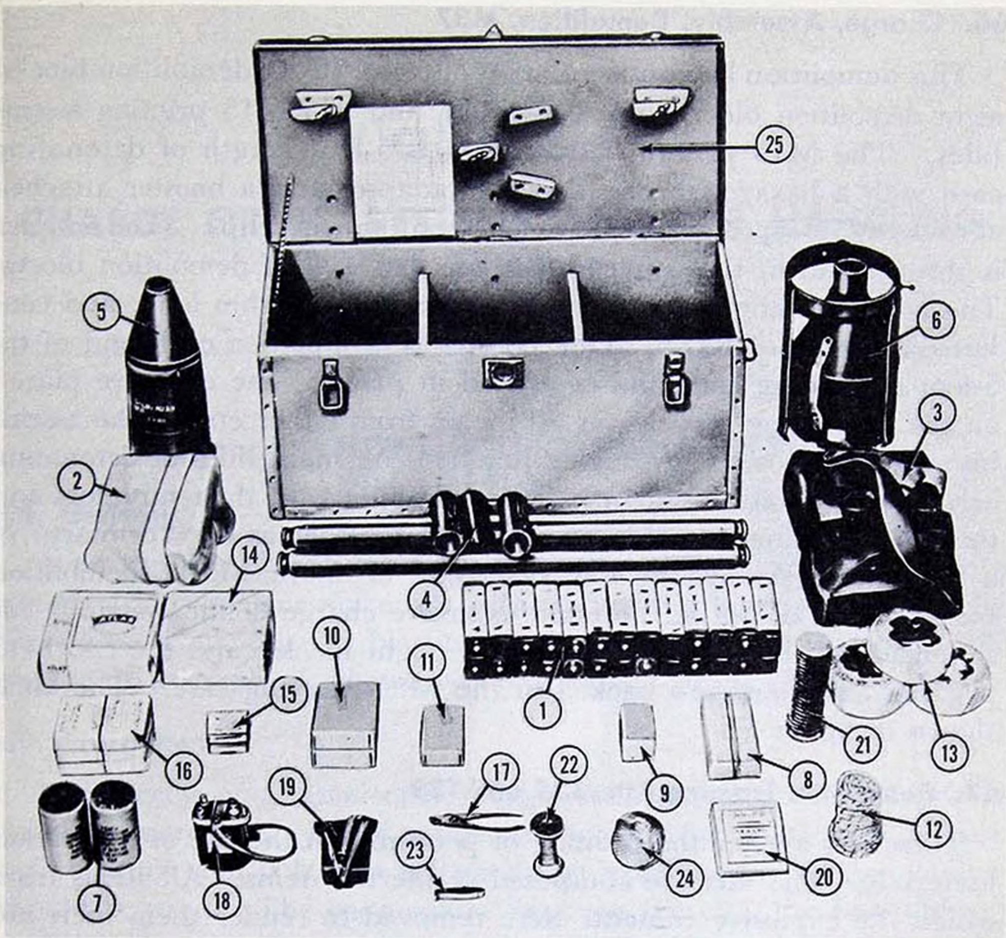
64. Demolition Equipment Set, Explosive Initiating, Electric and Nonelectric

The electric and nonelectric demolition equipment set consists of TNT and M5A1 (Composition C4) demolition blocks and accessories for electric and nonelectric priming. This demolition set is carried in the engineer platoon demolition chest.

65. Demolition Equipment Set, Explosive Initiating, Nonelectric

The nonelectric demolition equipment set consists of M5A1 (Composition C4) demolition blocks and accessories for nonelectric priming. This demolition set is carried in a canvas bag.

Figure 37. M-37 demolition kit.



1 26 EXPLOSIVE, TNT, 1-lb block, inert.
2 8 BLOCK, demolition, chain, M1, inert.
3 16 BLOCK, demolition, M5, inert.
4 1 TORPEDO, bangalore, M1A1, inert.
5 1 CHARGE, shaped, 15-lb, M2A3, inert.
6 1 CHARGE, shaped, 40-lb, M3, inert.
7 2 DETONATOR, concussion type, M1, inert.
8 50 ADAPTER, priming, explosive, M1A3.
9 50 CLIP, cord, detonating, M1.
10 10 FIRING DEVICE, pressure type, M1, inert.
11 5 FIRING DEVICE, pressure-release type, M5, inert.
12 4 CORD, detonating, inert (100-ft spool).
13 3 FUZE, time blasting, inert (100-ft spool).
14 100 CAP, blasting, special, electric (type II (J2 PETN)), inert.
15 100 CAP, blasting, tetryl, nonelectric, inert.
16 30 LIGHTER, fuze, weatherproof, M2, inert.
17 2 CRIMPER, cap (w/fuze cutter), M2.
18 1 MACHINE, blasting, 10-cap capacity.
19 1 GALVANOMETER, blasting, complete.
20 2 TAPE, friction, general use, grade A, ¾-in. wide, ½-lb roll.
21 1 WIRE, firing, 2-conductor, vinyl polymer covered, training, 250-ft roll.
22 1 WIRE, annunciator, single-conductor, cotton covered, 50-ft roll, training.
23 1 KNIFE, pocket, general purpose.
24 2 TWINE, hemp, No. 18, 4-oz ball.
25 1 CHEST, demolition squad.

Figure 38. Demolition training kit T-38.

66. Charge, Assembly, Demolition, M37

This demolition kit consists of a set of eight M5A1 demolition blocks, eight demolition block hook assemblies, and two M15 priming assemblies. The M15 priming assembly is a 5-foot length of detonating cord with a hexagonal-shaped plastic adapter and a booster attached at each end; it is provided with two detonating-cord clips. The adapter is threaded to fit the conventional size cap well of demolition blocks. The booster is about ¼ inch in diameter and 2 inches long; and contains a charge of RDX. One booster is crimped to each end of the 5-foot detonating cord and cemented in place. The clips are placed on the detonating cord about 20 inches from either end of the assembly; their purpose is to provide junctions on main lines of detonating cord in a detonation system. The main lines with their initiators and the M15 priming assembly can be used together as the "primary" of a demolition system; in this case, one or more M5A1 demolition blocks would comprise the main explosive charge of the system. For shipment and issue, the M5A1 blocks (eight blocks) and the two M15 priming assemblies are packed in the M85 carrying case. The kit is shown in figure 37.

67. Demolition Training Kits, T38 and T39

These kits are for the training of personnel in the use of demolition materials. The kits are composed of inerted items. All items from which the explosive contents were removed to render them inert are painted black. Haversacks, priming adapters, inert detonating cord, inert safety fuze, wires, instruments, and tools retain their normal colors or simulate the colors of their explosive counterparts. Inerted items used in these training kits are to be employed in exactly the same manner and with the same care and precautions as are the explosive items comprising the simulated demolition equipment sets. Therefore, it is essential that personnel, in training, be fully conversant with all procedures and instructions given in this manual pertaining to the explosive item of these simulated sets. The simulated sets are identical, except that kit T39 omits the following:

Bangalore torpedo.
Shaped charge—15 pounds.
Shaped charge—40 pounds.

The item letters are keyed to figure 38.

CHAPTER 5

CHARGE FIRING SYSTEMS AND THE HANDLING OF MISFIRES

Section I. NONELECTRIC FIRING SYSTEMS

68. General

A nonelectric firing system is one in which the explosive charge is detonated by nonelectric means. In this system, a slow-burning time fuze fires a nonelectric blasting cap, which in turn detonates the charge or a length of detonating cord leading to the charge.

69. Precautions

The success of a nonelectric firing system requires that the primer be made carefully. If the system is to stand for any length of time before firing or if it is in a wet or damp location, an M2 fuze lighter should be used. The connections between the cap, the fuze lighter, and the fuze must be waterproofed with cap sealing compound.

70. Nonelectric Primer

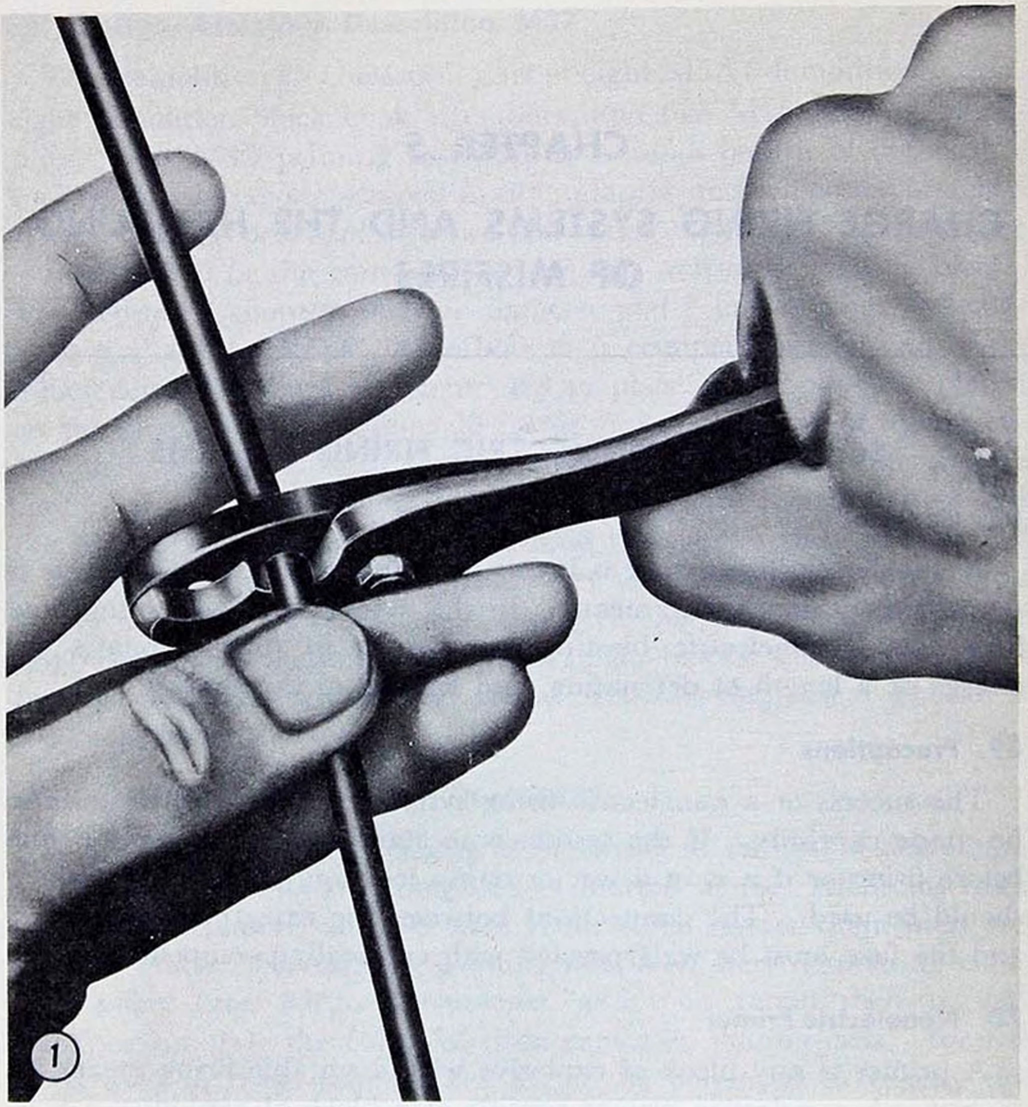
A primer is any block of explosive with a suitable firing means attached. A nonelectric primer consists of a block of explosive, a nonelectric blasting cap, and a length of fuze, together with whatever accessories (such as a priming adapter) that may be necessary to join these items into a single unit. It should be noticed that the nonelectric primer does not include any device for creating the spark to set off the charge. This is because a fuze lighter or a match, which will create the spark, is not considered a part of the primer.

71. Capping Fuze

The ends of a roll of time blasting fuze or safety fuze M700, exposed to the air, will absorb moisture in most climates. To avoid a misfire caused by a damp powder train, proceed as follows:

a. A 6-inch length is cut and discarded from the free end of the fuze. A measured length of the fuze should be ignited, burned, and timed to check the burning rate per foot.

b. The fuze is to be cut sufficiently long enough so that the person detonating the charge can reach a safe distance from the charge before it explodes. This cut should be square across the fuze (1, fig. 39).



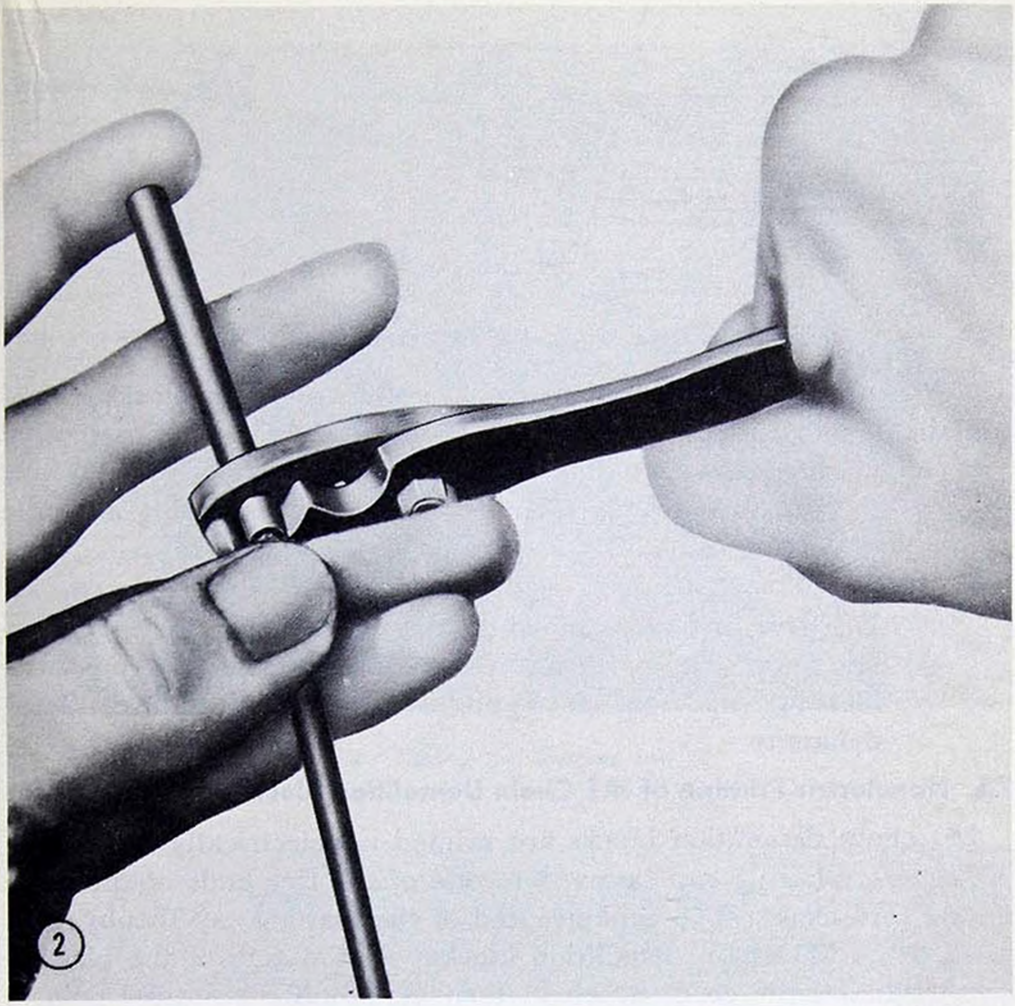
1 Cutting fuze

Figure 39. Method of using M2 cap crimper.

c. One blasting cap is to be taken from the cap box. It is to be held with the open end down and gently shaken to remove any dirt or foreign matter. The blasting cap is not to be tapped with or against a hard object.

d. Holding the fuze vertically with the cut end up, the blasting cap is gently slipped down over the fuze, so that its explosive is in contact with the end of the fuze. The fuze is not to be forced into the blasting cap. If the end of the fuze is flattened or is too large to enter the blasting cap freely, it is to be rolled between thumb and fingers until it reaches a size and shape which will permit its free entry into the cap.

e. When the blasting cap is seated on the fuze, the fuze is grasped between the thumb and the third finger of the left hand and the forefinger is extended over the end of the cap to hold it firmly against the end of the fuze.



2 Crimping cap on fuze

Figure 39—Continued.

f. The third finger is slid up to the edge of the blasting cap to guide the crimpers during crimping operations (2, fig. 39) and to permit accurate crimping, even in darkness.

g. The blasting cap is then crimped near the open end (¼ to ½ inch from the open end).

Caution: A crimp too near the explosive in the blasting cap may cause detonation. The blasting cap is to be pointed out and away from the body while crimping.

h. If the blasting cap is to be left in place several days before firing, the joint between the cap and the fuze is to be protected with a coating of sealing compound or soap.

72. Nonelectric Priming of TNT

a. TNT demolition blocks containing a threaded cap well can be primed nonelectrically (fig. 40) by using a priming adapter as discussed in paragraph 51.

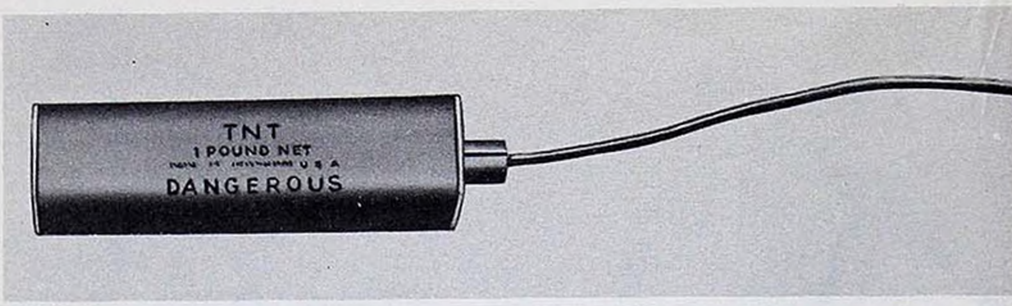


Figure 40. One-pound block of TNT primed nonelectrically.

b. When priming adapters are not available, or when blocks do not contain threaded cap wells, the following procedure can be used:

(1) A string is wrapped tightly around a block and tied securely over the cap well, leaving about 6 inches of loose string after the tie has been made.

(2) The loose string is to be pushed aside and a blasting cap inserted, with fuze attached, in the cap well.

(3) The loose string is to be tied around the fuze to protect the blasting cap from any pull as shown in 3, figure 42 for dynamite.

73. Nonelectric Priming of M1 Chain Demolition Block

M1 chain demolition blocks are primed nonelectrically by using a nonelectric blasting cap fastened to one of the free ends of the detonating cord chain. The explosive end of the blasting cap should point toward the M1 chain demolition blocks. Detonation of the blasting cap detonates the cord, which in turn detonates the entire chain of blocks.

74. Nonelectric Priming of Plastic Explosives

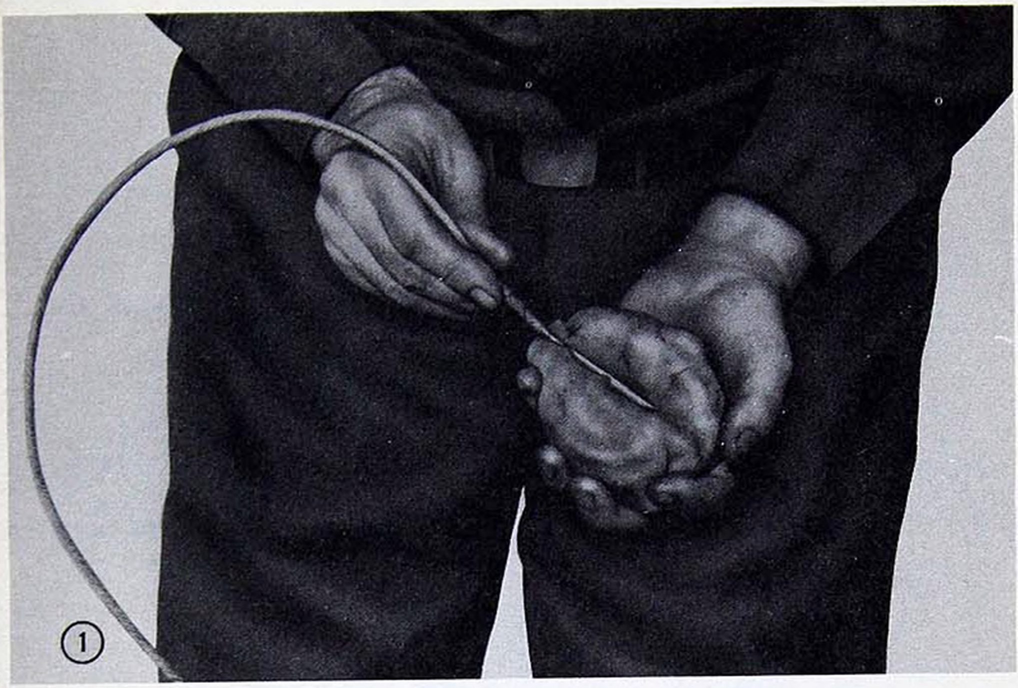
Compositions C3 and C4 are primed nonelectrically with a nonelectric blasting cap by molding the explosive around the fuzed cap (1, fig. 41). The explosive must be at least 1 inch thick at the ends of the blasting cap and ½ inch thick on the sides to insure detonation (2, fig. 41). If the explosive is cold and brittle, it should be warmed by body heat, or by working it with the hands, or by holding it in warm water. It must not be warmed over an open flame nor exposed to extreme heat. The fuze is tied to the same object to which the charge is fastened to prevent the blasting cap from being pulled out of the explosive.

75. Nonelectric Priming of Dynamite

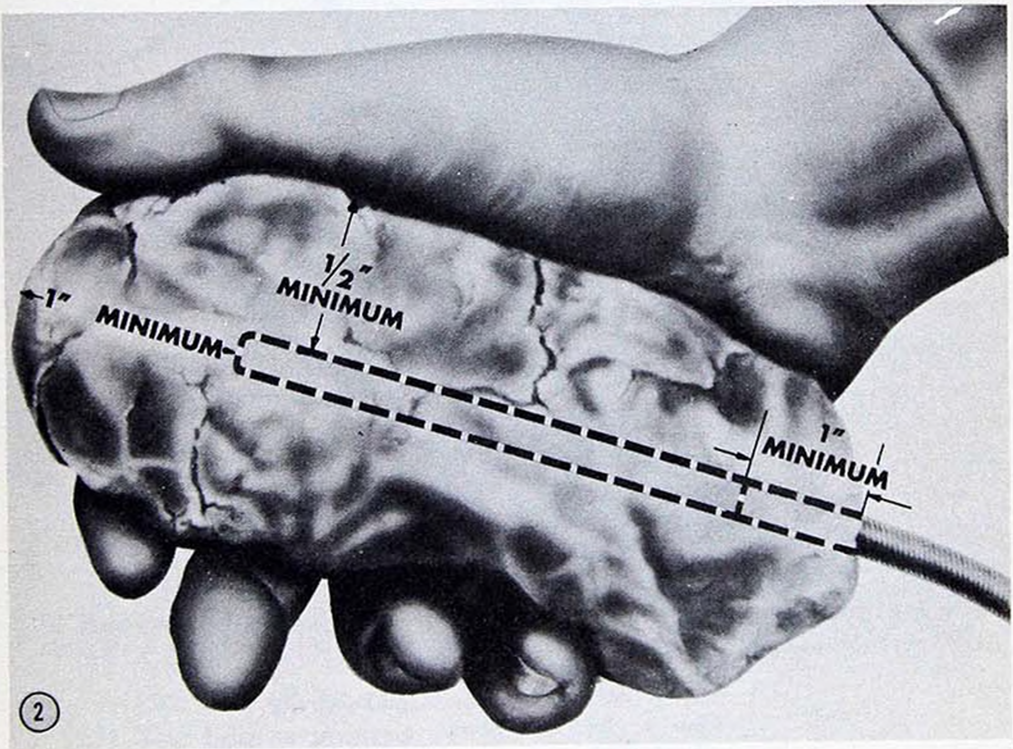
Dynamite is primed nonelectrically either at one end or on the side. End priming is generally used either when whole case lots are to be fired or when charges are so placed as to require no tamping.

a. End Priming Method.

(1) A hole is punched in the end of the cartridge (1, fig. 42).

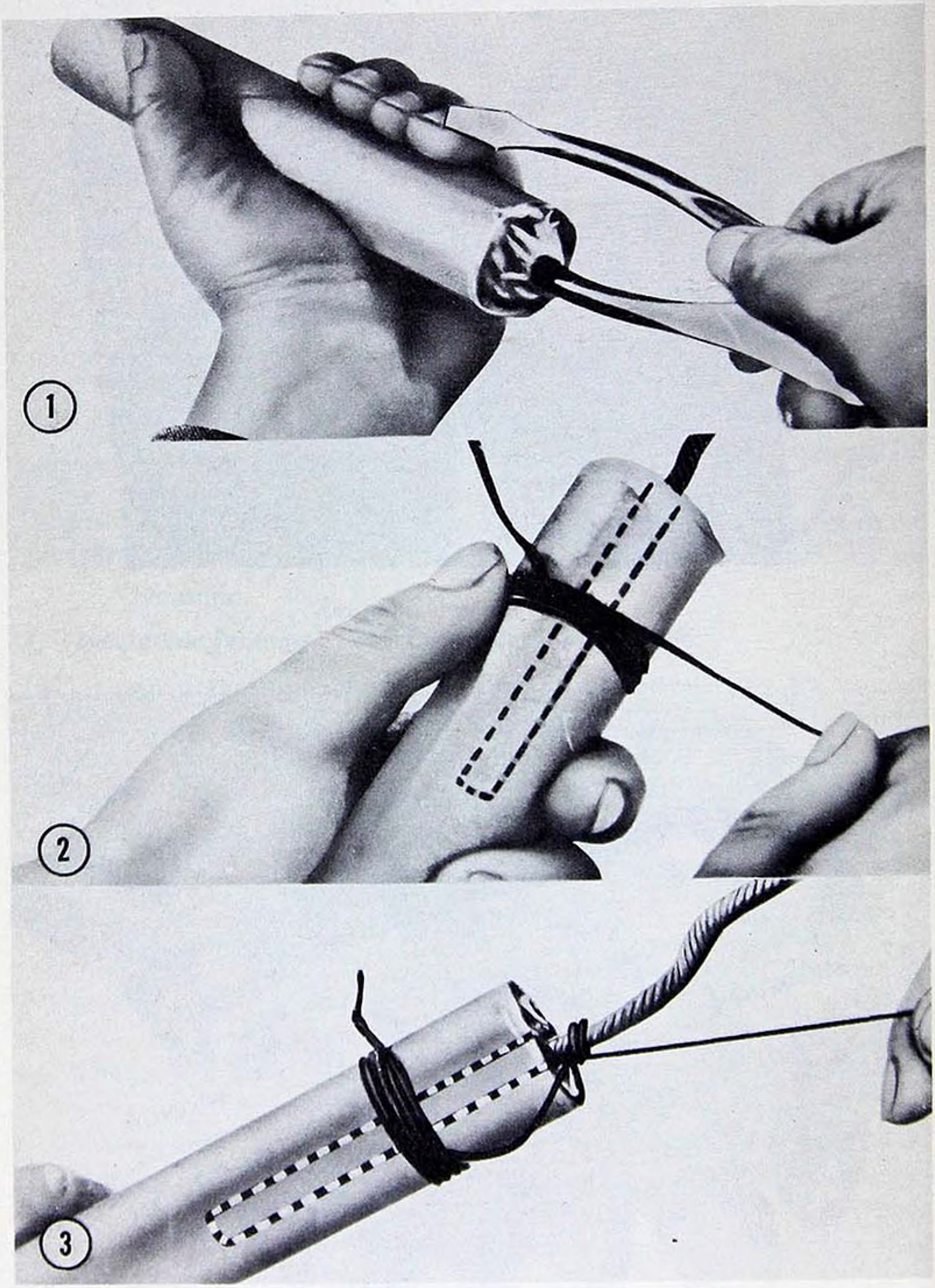


1 Placing the blasting cap



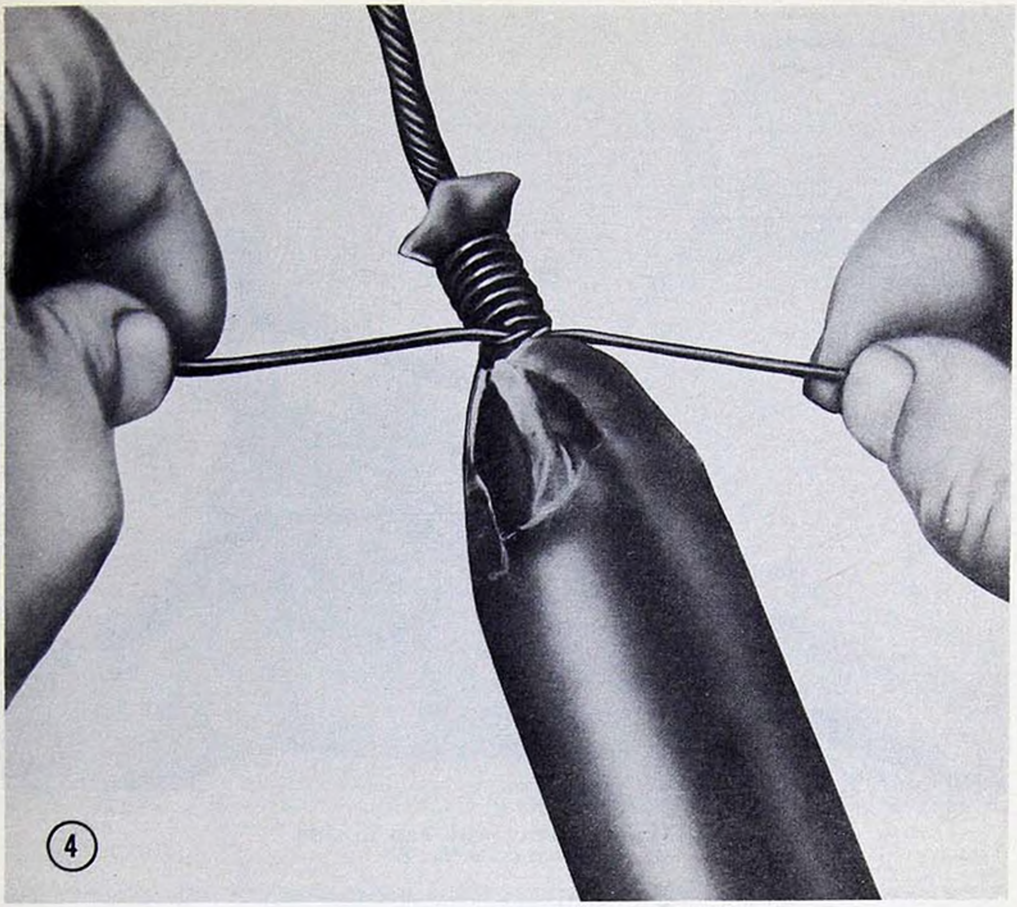
2 Blasting cap in place

Figure 41. Plastic explosive charge primed nonelectrically.



1 Using M2 cap crimper to make cavity
2 Cap in place and tying
3 Tying fuze

Figure 42. Dynamite primed nonelectrically with cap in end.



4 Alternate and priming method

Figure 42—Continued.

(2) A fuzed blasting cap is inserted (2, fig. 42).

(3) The cap and fuze are tied as shown in 2 and 3, figure 42.

b. Alternate End Priming Method.

(1) The wrapping at one end of the cartridge is unfolded.

(2) The end of the cartridge is to be rolled in the hands to loosen the dynamite.

(3) A hole is punched in the exposed dynamite.

(4) A fuzed blasting cap is inserted in the hole.

(5) The wrapping is closed.

(6) It is fastened securely with string or tape as shown in 4, figure 42.

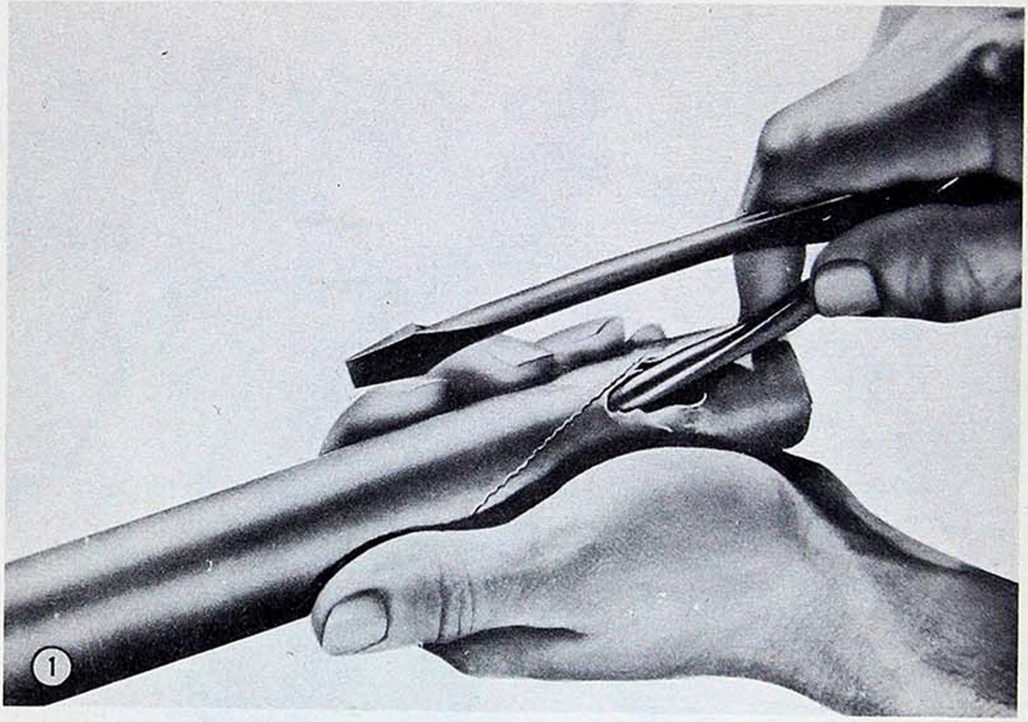
c. Side Priming Method.

(1) A hole is to be punched in cartridge about 1½ inches from one end (1, fig. 43).

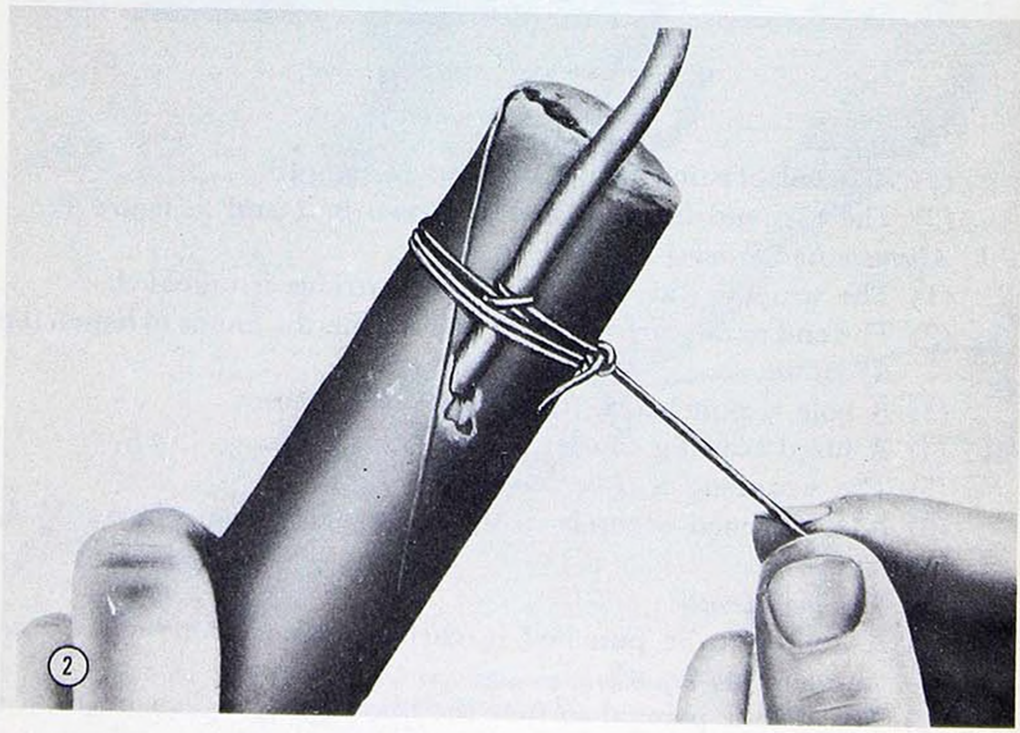
(2) The hole is pointed so that the blasting cap, when inserted in it, will be nearly parallel to the side of the cartridge, with the explosive end of cap at the center of the cartridge.

(3) A fuzed blasting cap is slipped into the hole.

(4) A string is wrapped tightly around the fuze and then around

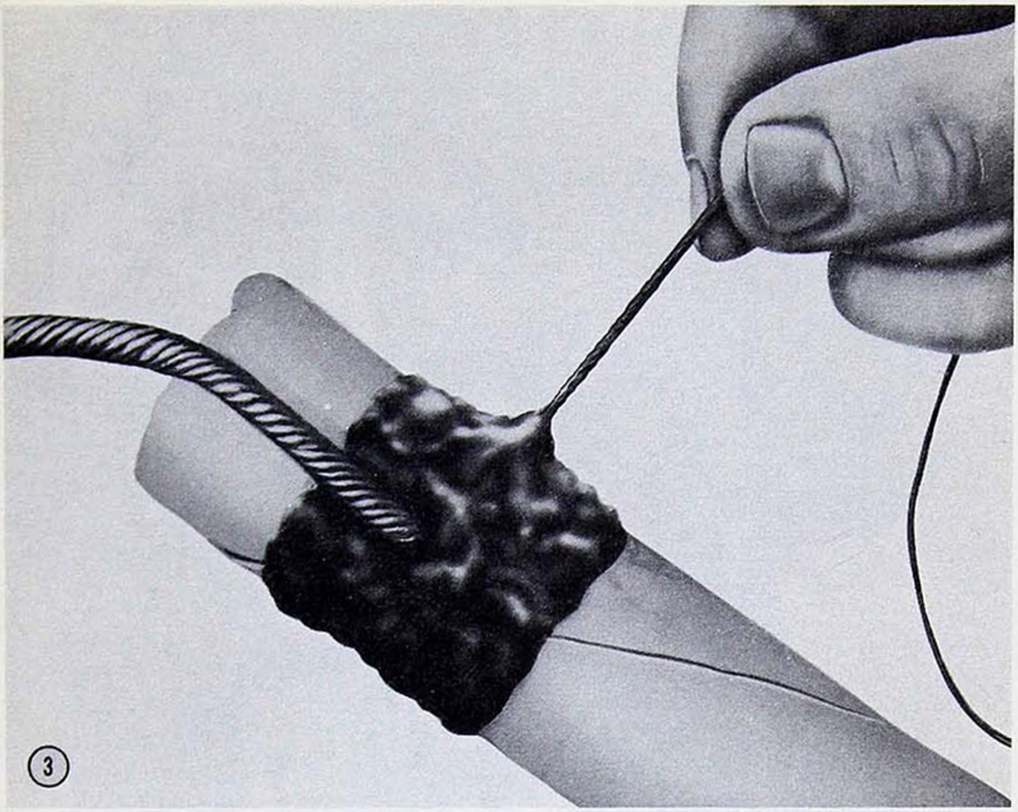


1 Making cavity with cap in side



2 Cap in place and tying

Figure 43. Dynamite primed nonelectrically with cap in side.



3 Waterproofing

Figure 43—Continued.

the cartridge, making 2 or 3 tight turns before tying the string (2, fig. 43).

(5) The primer is moistureproofed by using a longer string and wrapping it closely around the cartridge to cover the cartridge completely, for about 1 inch on each side of the hole. The string is then covered with a water-repellent substance (3, fig. 43).

76. Nonelectric of Ammonium Nitrate Cratering Charge

The ammonium nitrate 40-pound charge is generally used for cratering. When used in boreholes, it is not primed nonelectrically because simultaneous firing of several charges so primed is not practical. For other applications, the ammonium nitrate 40-pound charge is primed nonelectrically as follows:

a. A fuzed blasting cap is to be placed in the cap well on the side of the can (1, fig. 44).

b. A string is tied around the fuze and then around the cleat above the blasting cap (2, fig. 44).

77. Nonelectric Misfires

a. Prevention of Nonelectric Misfires. Working on or near a misfire is the most hazardous operation associated with blasting. A misfire should

1 Inserting cap into well

Figure 44. Ammonium nitrate cratering charge primed nonelectrically.

be an extremely rare occurrence if the following points are always given close attention:

(1) Primers must be prepared properly.

(2) Charges must be loaded carefully.

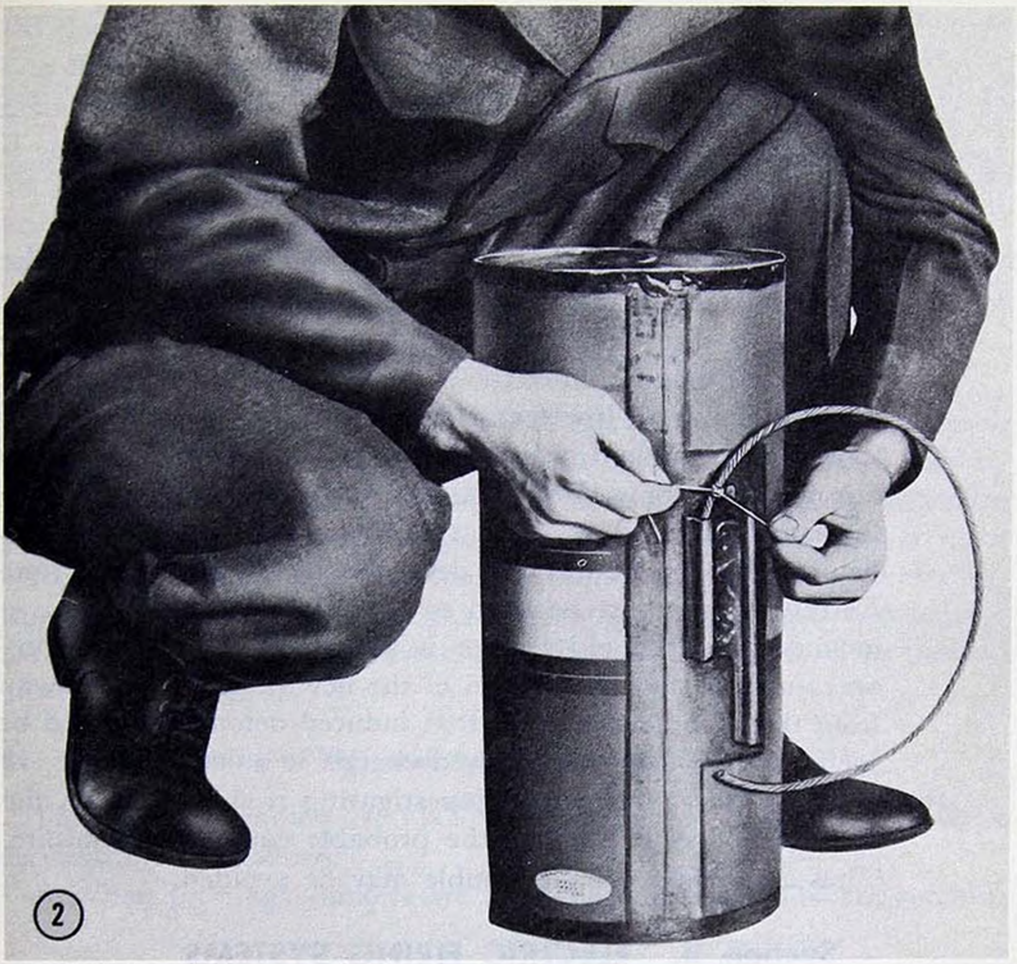
(3) The primer must be properly placed.

(4) Any tamping operation must be performed with care so as not to damage an otherwise carefully prepared charge.

(5) Proper technique must be used in firing the charge.

(6) If possible, dual firing systems should be used (pars. 106–109). If both systems are properly constructed, it is almost a certainty that at least one of the systems will fire the charge properly.

b. Handling Nonelectric Misfires. Occasionally a nonelectric misfire will occur. Investigation and correction of the trouble should not be undertaken by a person unfamiliar with explosives. Such investigation is a hazardous operation which should be accomplished by a demolition specialist. For handling misfires involving detonating cord, see para-



2 Tying fuze to cleat

Figure 44—Continued.

graph 105. For a charge primed with nonelectric cap and time fuze, the following is the recommended procedure:

(1) Investigation of the misfire should be delayed at least 30 minutes. This should give ample time for any delayed explosion to take place. Such a delayed explosion could result from a defective powder train in the fuze. Under certain combat situations, a delay might not be possible. Immediate investigation, with the attendant risk to the person investigating the misfire, might be necessary.

(2) If the misfired charge is not tamped, a new primer is to be inserted in the charge and refired.

(3) If the charge is tamped with only a foot or so of earth covering, an attempt should be made to explode the misfire by detonating a new primer placed top of the earth covering.

(4) If the misfired charge is located deep in a tamped borehole, or if the tamped charge is so situated as to make the method outlined above impracticable, it will be necessary to remove

the tamping. This should not be done with metal tools because of the possibility of digging into the charge itself and detonating it. Instead, a wooden tool or stick should be used to remove tamping. If compressed air (or pumped water) is available, the tamping can be blown out with a stream of air (or water). Stiff rubber hose is to be used in this method of removing tamping. If the depth of the borehole from the ground surface to the top of the charge is observed when the tamping is started, periodic depth checks will minimize the danger of digging into the charge. When the charge is nearly uncovered, insert and detonate a new primer.

(5) An alternate method of reaching a deep misfired charge is to dig or drill a new hole within a foot of the old one and to the same depth. A small charge with a new primer can then be placed in this new hole to detonate the old misfired charge. Extreme care must be used so that the new hole is not so inclined that the old charge is struck by the new digging operation, or that the bottom of the new hole is too far away from the misfired charge so that induced detonation would be ineffective in firing the misfired charge.

(6) In any misfire, the person investigating it should be on the alert to notice, if possible, the probable cause of the misfire. Thus a repetition of the trouble may be avoided.

Section II. ELECTRIC FIRING SYSTEMS

78. General

An electric firing system is one in which the initiating medium for the detonation is an electric spark or impulse. The electric impulse travels through a cap's lead wires to the electric blasting cap and fires it. The cap, having been placed in an explosive charge to form an electric primer, then detonates the explosive charge.

79. Electric Primer

An electric primer consists of a block of explosive, an electric blasting cap, and whatever accessories (such as a priming adapter) are necessary to join the explosive and the cap into a single unit. The electricity-producing firing device may be a blasting machine or other suitable generator and includes a firing wire.

80. Testing Electric Blasting Caps

Before using a blasting cap to construct an electric primer, the cap should be tested with a galvanometer to determine that it is not defective. After first testing the galvanometer (par. 59*b*), and then removing the short-circuit shunt from the electric blasting cap (par. 45*a*), connect one post of the galvanometer to one lead of the cap and

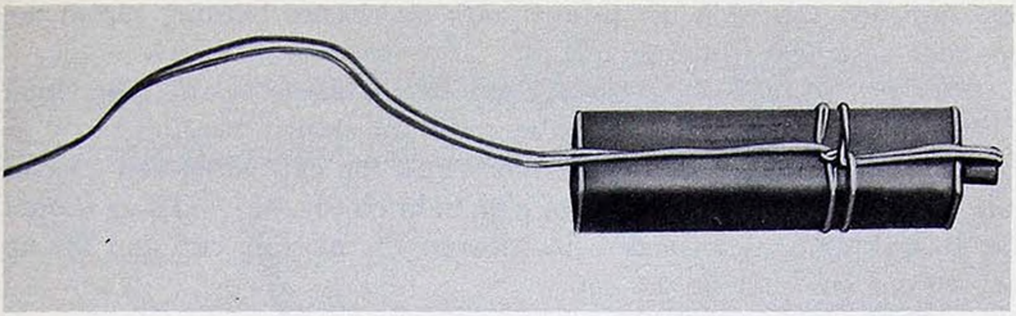


Figure 45. One-pound TNT block primed electrically.

the other post of the galvanometer to the other lead of the cap. If the instrument registers a flowing current, the blasting cap is satisfactory. If not, it is a defective cap and should not be used. Defective caps should be destroyed by placing them in a charge that is to be fired. Use of a stronger cell than recommended for use with the galvanometer might easily cause the blasting cap to detonate. Whenever making this test, the explosive end of the blasting cap is to be pointed away from the body.

81. Electric Priming of TNT and the M2 Demolition Block

The electric priming of TNT and of the M2 demolition block is accomplished as follows:

a. When priming adapters are available, demolition blocks contain-

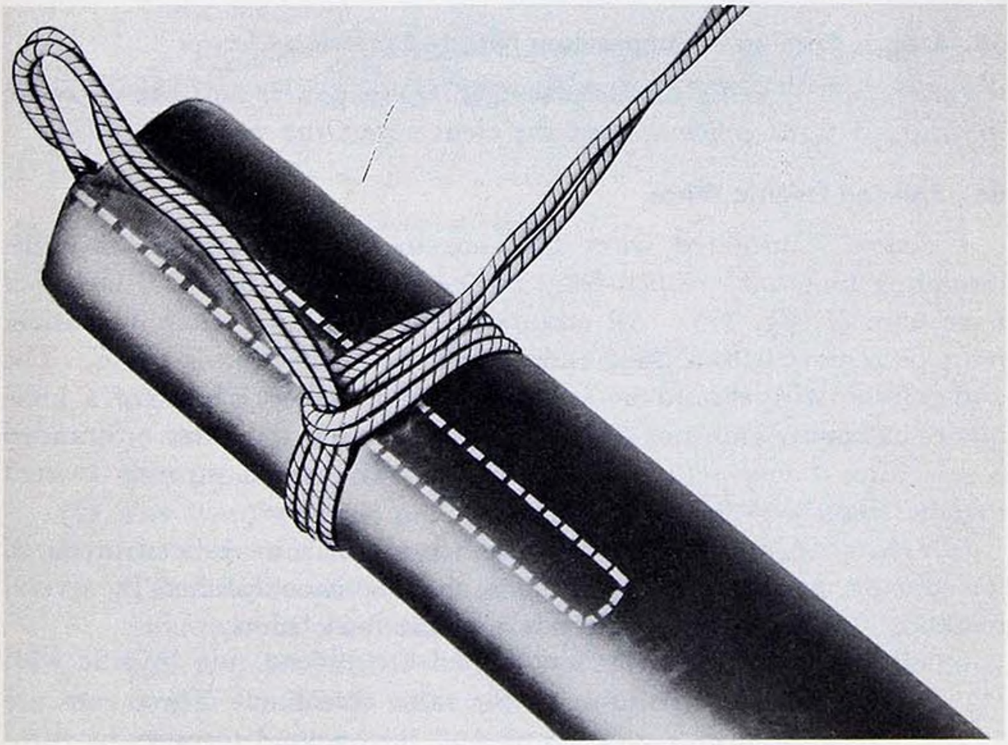


Figure 46. Dynamite primed electrically.

ing threaded cap wells are primed with an electric blasting cap in the manner described in paragraph 51.

b. When priming adapters are not available or when demolition blocks do not contain threaded cap wells, an electric blasting cap is to be inserted into the well of the block and the cap wires tied around the block with two half-hitches or a girth hitch (fig. 45). There should be a small amount of slack wire between the blasting cap and the tie to prevent any pull on the cap.

82. Electric Priming of M1 Chain Demolition Block

Electric priming of M1 chain demolition blocks is no different from nonelectric priming (par. 73) except that an electric blasting cap is substituted for the nonelectric blasting cap and time fuze.

83. Electric Priming of Plastic Explosives

The plastic explosives (compositions C3 and C4) are primed electrically in the same manner as they are primed nonelectrically (par. 74) except that electric blasting caps are substituted for the fuzed nonelectric blasting caps.

84. Electric Priming of Dynamite

Dynamite may be primed electrically using the same procedure as for nonelectric priming. The blasting cap is held in place by tying the lead wires around the cartridge with a girth hitch or two half hitches (fig. 46).

85. Electric Priming of Ammonium Nitrate Cratering Charge

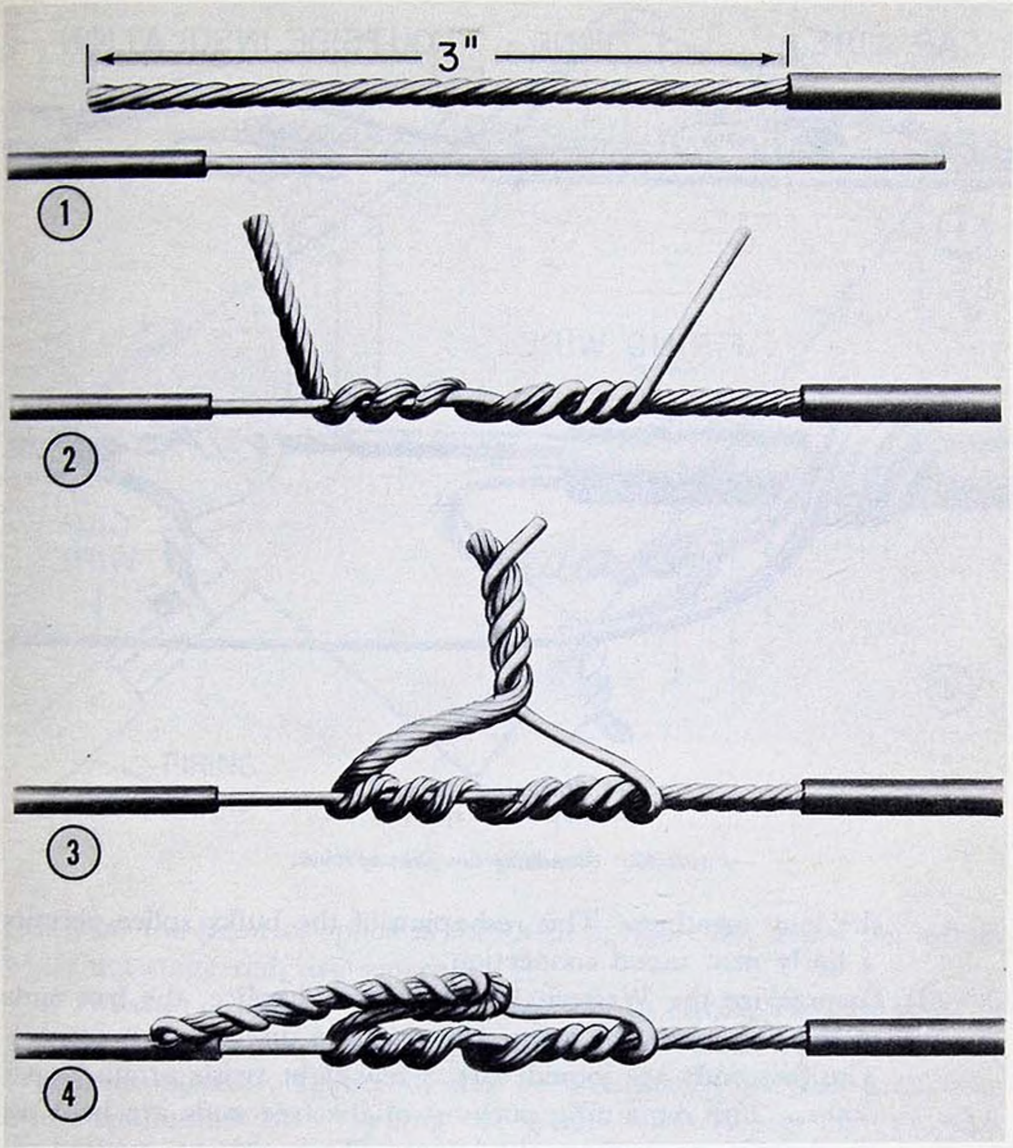
An electric blasting cap is placed in the cap well and the cap wire is wrapped three times around the cleat above the well.

86. Splicing Electric Wires

a. General. Insulated wires that are to be spliced must have the insulating material stripped from the ends to expose about 3 inches of bare wire (1, fig. 47). All enamel, as well as any other insulation, must be removed from these ends before the connection is made. The ends of the wire should be scraped lightly with the back of a knife blade, exercising care not to nick, cut, or weaken the wires. Stranded wires, after being scraped, should have the small strands twisted together tightly to form a single lead.

b. Types of Splices. Connecting two wires which have been prepared for splicing, as described in *a* above, may be accomplished by several methods. Some of these methods are described below.

(1) The two wires to be connected are placed side by side with the free ends pointing in the same direction. These ends are bent to form a short crank and then wound together by turning this crank. This gives a tight connection which becomes

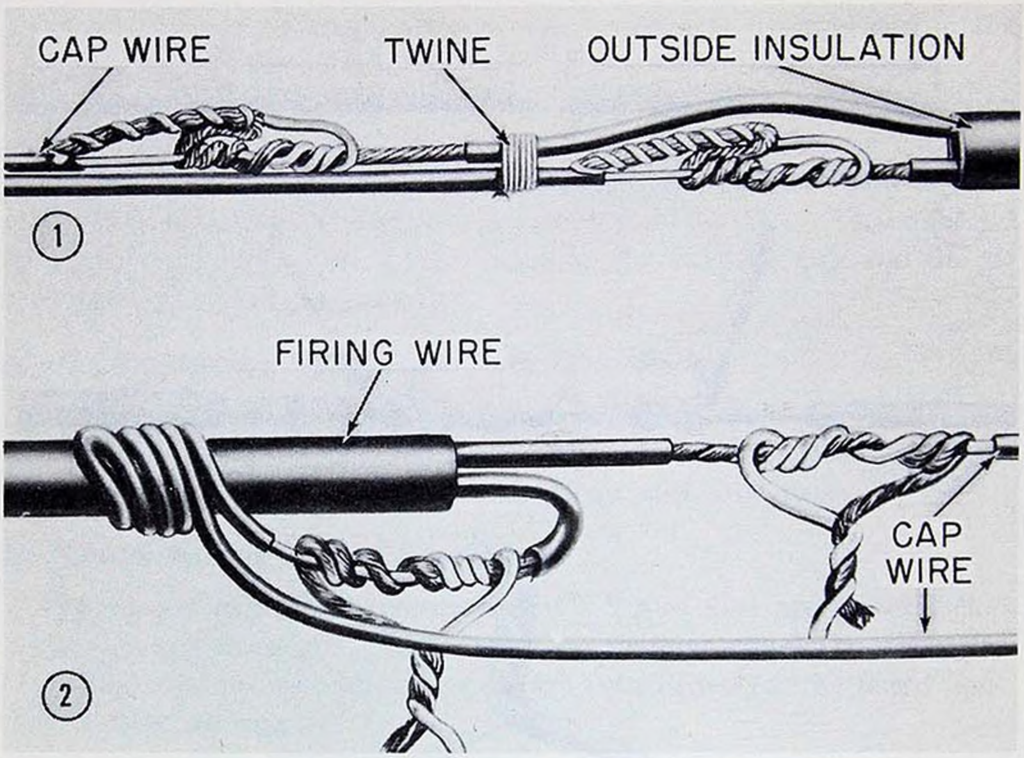


1 Stripping wires
2 First step of splice
3 Second step of splice
4 Completed splice

Figure 47. A method of splicing wires.

tighter if pulled. Although this connection is at right angles to the wire, it can be bent along one side of one wire before any taping operation is undertaken.

(2) The two free ends are placed side by side, and about half of the free ends are bent back onto the other half of the ends. Then the loop that is formed is grasped with the thumb and forefinger of one hand while holding the running ends of the pair in place with the other hand. The loop is then twisted to join the wires. The resulting splice is a little more bulky than the method in (1) above but it is a quick and efficient splice. If it is desired to tape the splice, pinch the sides of



1 Staggered splice
2 Separated splice

Figure 48. Connecting two pairs of wires.

the loop together. This reshaping of the bulky splice permits a fairly neat taped connection.

(3) To produce the Western Union "pigtail" splice, the free ends of the two wires are pointed in opposite directions (1, fig. 47). The free ends are joined with a few tight twists around each other. The remaining portions of the free ends are bent up (2, fig. 47), away from the joint. These ends are twisted together to form a "pigtail" (3, fig. 47). The pigtail portion of this splice is at right angles to the wires connected. The pigtail can be pushed to one side to lie along one of the wires before any taping operation is undertaken (4, fig. 47).

(4) Any other splicing method would serve satisfactorily provided it meets two requirements: the splice should not appreciably reduce the tensile strength of the wire; the splice should not materially increase the electrical resistance of the wire.

c. Staggered Splices. One pair of electrical conductors is joined to another pair of electrical conductors by splicing the individual wires (one of one pair to one of another pair, and the second of one pair to the second of the other pair) to one another, as explained in *b* above. In order to prevent a short circuit at the point of splice, the two separate splices are staggered and tied with tape or twine as shown in 1, figure 48. An alternate method of preventing a short

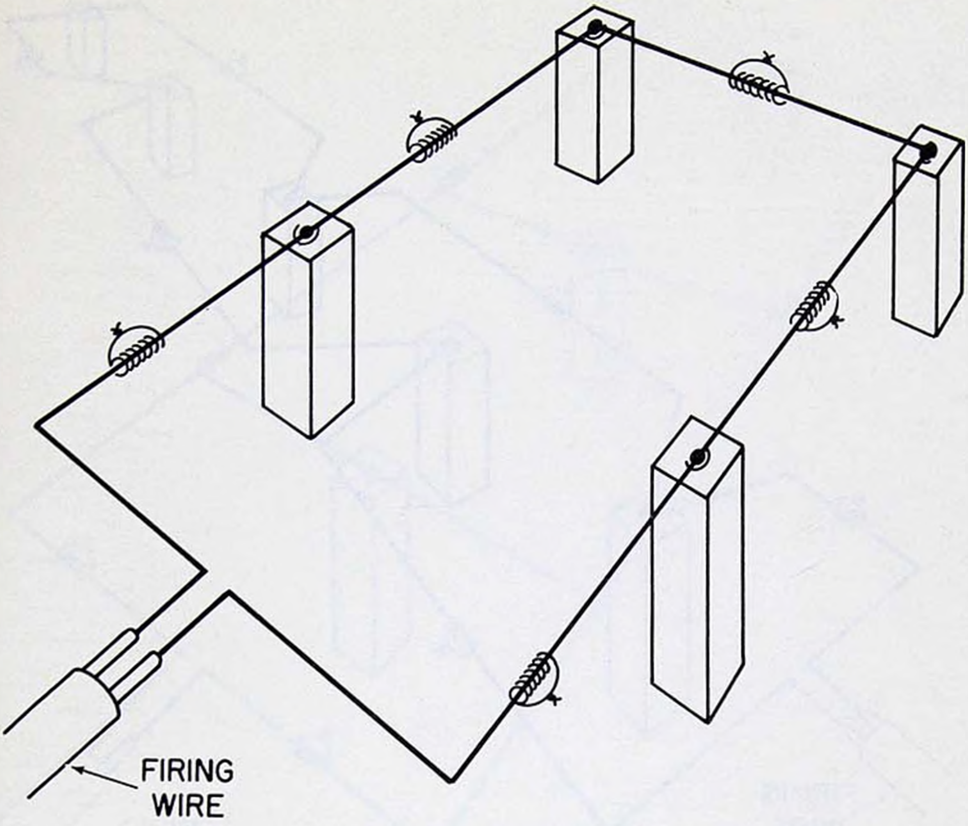


Figure 49. Common series circuit.

circuit at the point of splice is shown in 2, figure 48, where the splices, while not staggered, are separated.

d. Protection of Splices. Bare wire splices in wiring circuits must be protected to prevent short circuiting to the ground or to each other. Whenever possible, splices should be insulated from the ground or other conductors by wrapping the splices with friction tape or other electrical insulating tape. This is particularly essential in the case of splices placed under wet tamping. When circuits lie on moist ground, splices not taped or otherwise insulated must be supported on rocks, blocks, or sticks so that only the insulated portions of the wires touch the ground.

87. Circuits

a. Series Circuits. A series circuit (fig. 49) is used for connecting two or more charges fired electrically with a blasting machine. Charges are connected in series by connecting one wire from the blasting cap in the second charge, and so on until only two end wires are free. These two free end wires are then connected to the ends of the firing wire. Connecting wires are used when the distance between blasting caps is greater than the length of the usual lead wires. The "leapfrog" method of connecting caps in series (fig. 50) is useful for connecting a long line of charges. It should be noticed in figure 50 that the "leapfrog" method consists merely of omitting alternate charges on

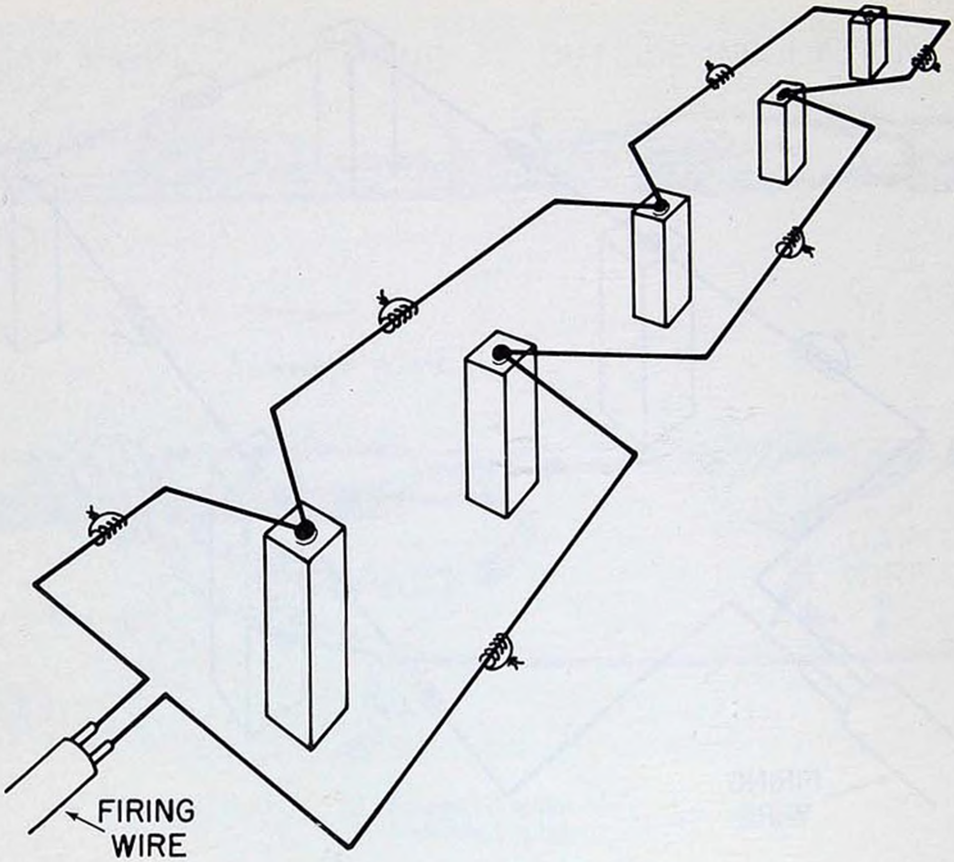


Figure 50. "Leapfrog" series circuit.

the way out from one lead of the firing wire and then connecting these skipped charges so as to form a return path for the electric impulse to reach the other lead of the firing wire. This permits both end wires to be brought out at the same end of the line of charges, thereby saving the necessity for a long return lead to be laid from the far end of the line of charges back to the firing wire.

b. Parallel and Series-Parallel Circuits. A parallel electrical circuit (fig. 51) or a series-parallel electrical circuit (fig. 52) may be used in the electric firing of explosives only when an adequate source of power is available, as outlined in appendix II. These circuits should be used only by an expert blaster because they must be accurately balanced to insure detonation of all charges. Inaccurate balancing may cause a misfire. Appendix II gives power requirements for multiple firing circuits.

88. Induced Radio Frequency (RF) Currents

The probability of prematurely detonating electric blasting caps by induced RF (radio frequency) currents is extremely remote. The possibility does exist, however. Table VII of minimum safe distance versus transmitter power indicates the distance beyond which it is safe to conduct electrical blasting operations even under the most adverse con-

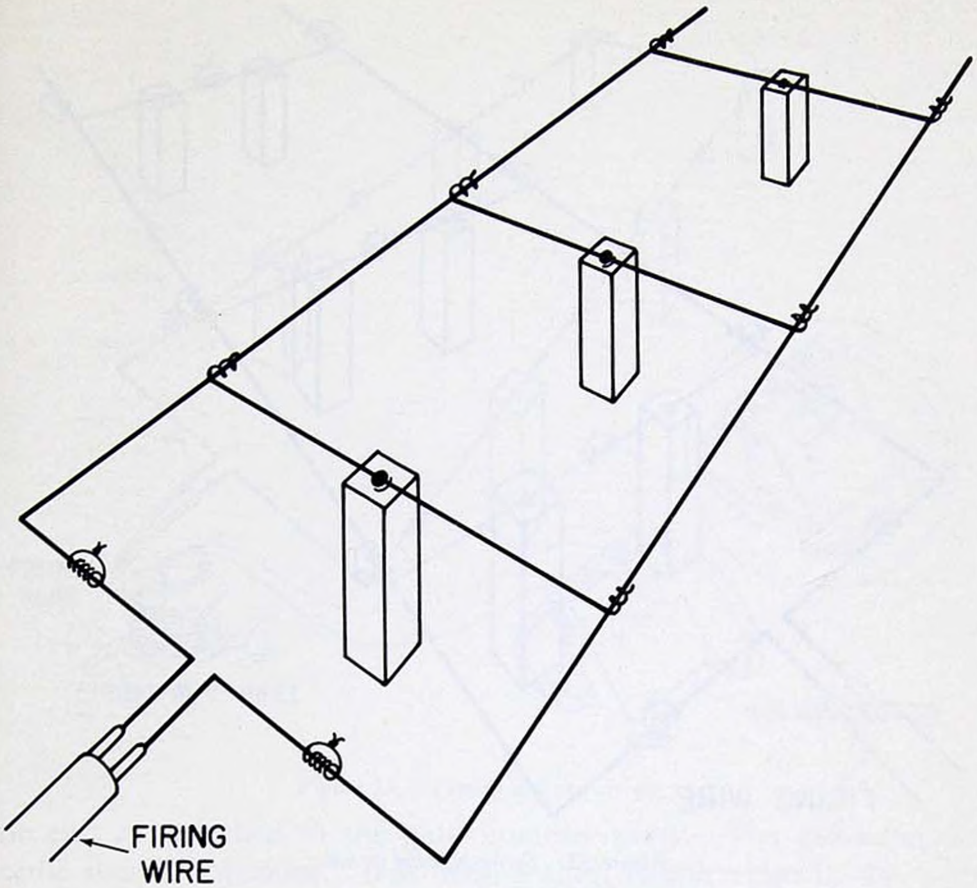


Figure 51. Parallel circuits.

ditions. Mobile type transmitters shall be prohibited within 150 feet of any electrical blasting caps or electrical blasting system. There are two possible courses of action that can be taken when it becomes necessary to perform blasting operations at distances less than those shown in this table.

Table VII. Minimum Safe Distances for RF Transmitters

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

a. The first course of action is to use a nonelectric blasting system. This procedure should be used, if at all possible, because there is no danger whatsoever of a premature detonation due to RF currents.

b. The second course of action is to use an electrical blasting sys-

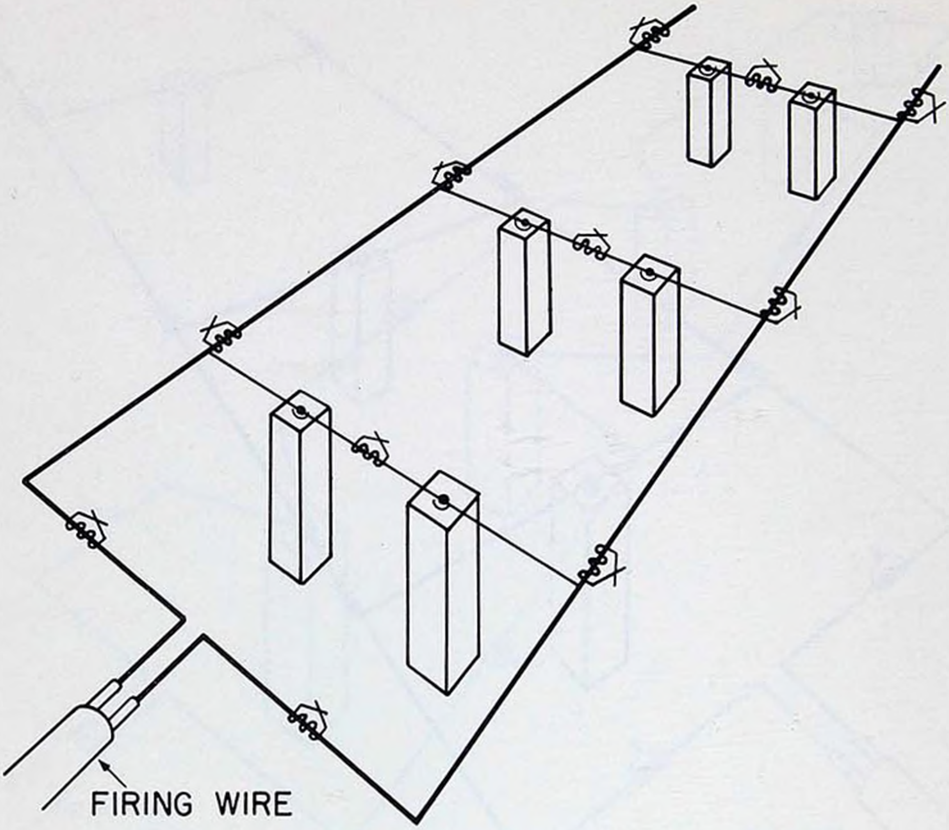


Figure 52. Series-parallel circuit.

tem, taking the following precautions in order to minimize the possibility of a premature detonation of the electric blasting cap by induced RF currents.

(1) All of the usual safety precautions for electrical blasting operations are observed.

(2) All firing wires are covered with dirt.

(3) A regularly twisted wire such as W–110/B or WD–1–TT is used.

(4) The full length of all cap leads are twisted when they are removed from their original individual containers.

(5) The number of caps are kept at a minimum, preferably one.

89. Testing Circuits

A circuit should always be tested before firing. The galvanometer is tested before performing any of the tests described in paragraphs 90 through 92.

90. Testing Firing Wire

The firing wire can be tested while on the reel but should be tested again after it has been unreeled. Uncoiling the wire may cause separation of broken wires not noticeable when on the reel.

a. Wires are to be separated at each end of firing wire. Wires at

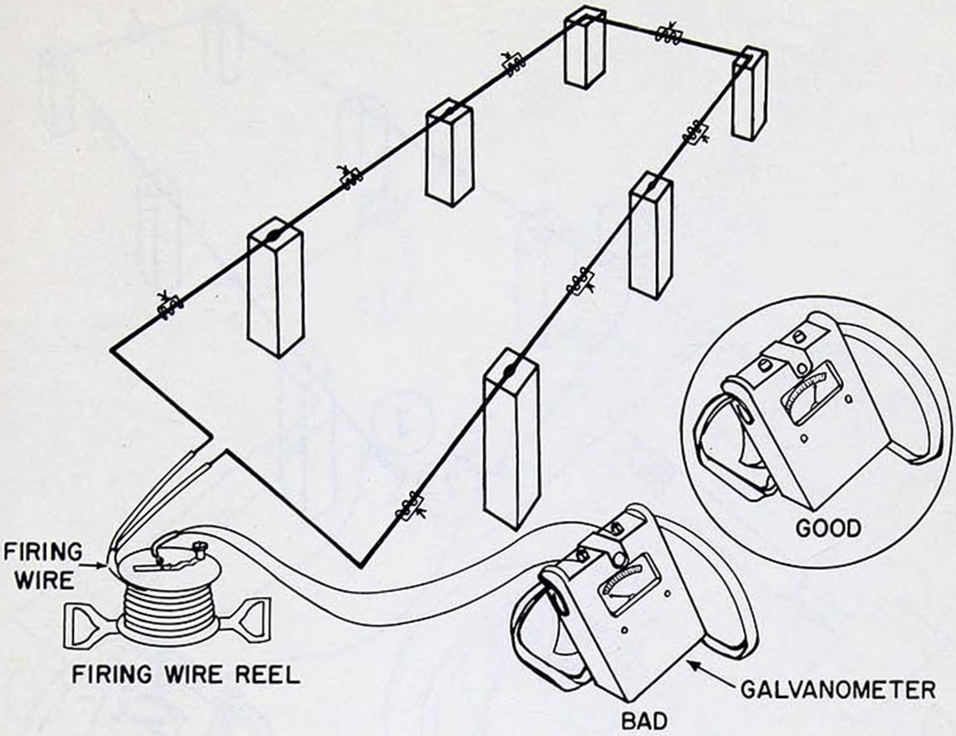


Figure 53. Testing a firing circuit.

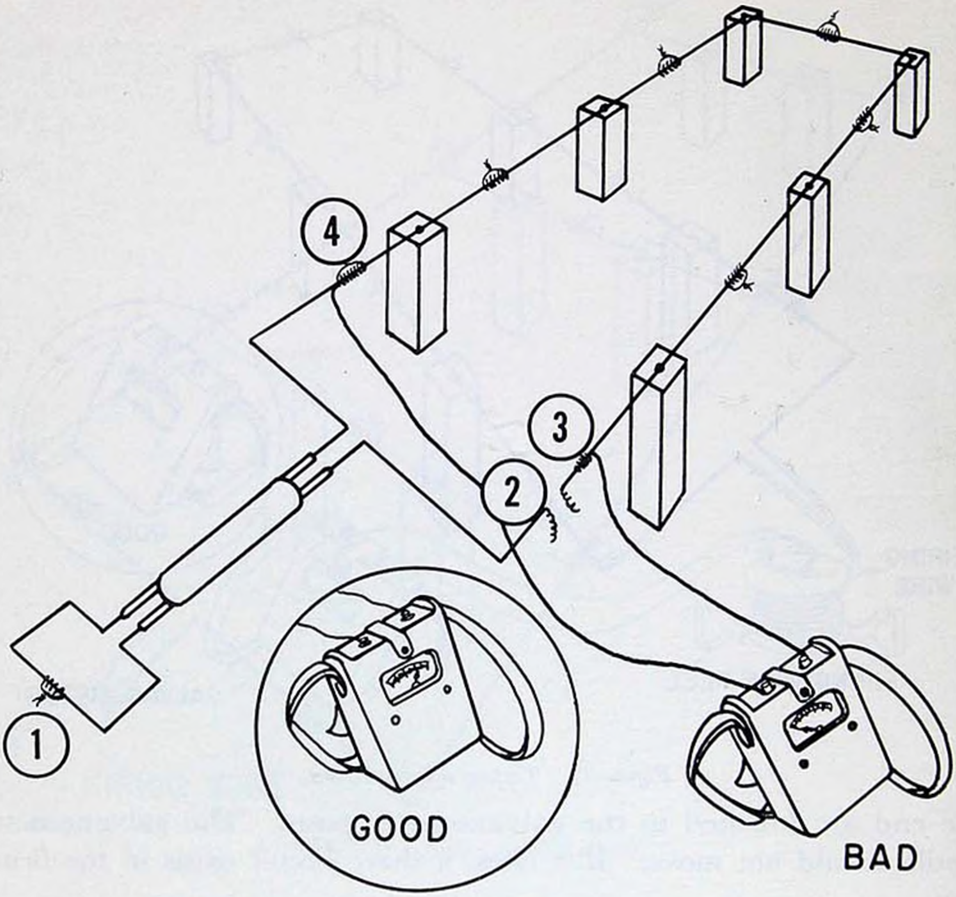
one end are touched to the galvanometer posts. The galvanometer needle should not move. If it does, a short circuit exists in the firing wire.

b. The wires are twisted together at one end, and those at the other end are touched to the galvanometer posts. This should cause a wide deflection of the galvanometer needle. No movement indicates a break in the firing wire; slight movement indicates a point of high resistance in the circuit.

91. Testing Entire Circuit

a. Limitations of Test. A test of the entire circuit will reveal the existence of any breaks in the circuit. But a test of the entire circuit will neither detect short circuits nor guarantee the inclusion of all charges in the circuit. Omissions and short circuits are prevented by exercising extreme care in making the connections and by making a careful visual check before firing the charge. All joints and bare sections of wire must be separated from each other and placed out of contact with the ground and all other conductors.

b. The Test. When the entire circuit, including the firing wire, has been connected, the circuit is tested by touching the ends of the firing wire to the galvanometer terminals (fig. 53). If the galvanometer needle does not move, a break exists in the circuit. If the needle does move across the scale, a complete circuit exists. The amount of deflection of the galvanometer needle depends on the length of the firing wire and on the number of blasting caps in the circuit. If a break is indicated it must be located as described in paragraph 92.



1 Splicing firing wires from the blasting machine
2 Opening the circuit
3 Touching one galvanometer lead to blasting cap lead wire
4 Touching the other galvanometer lead to last blasting cap wire

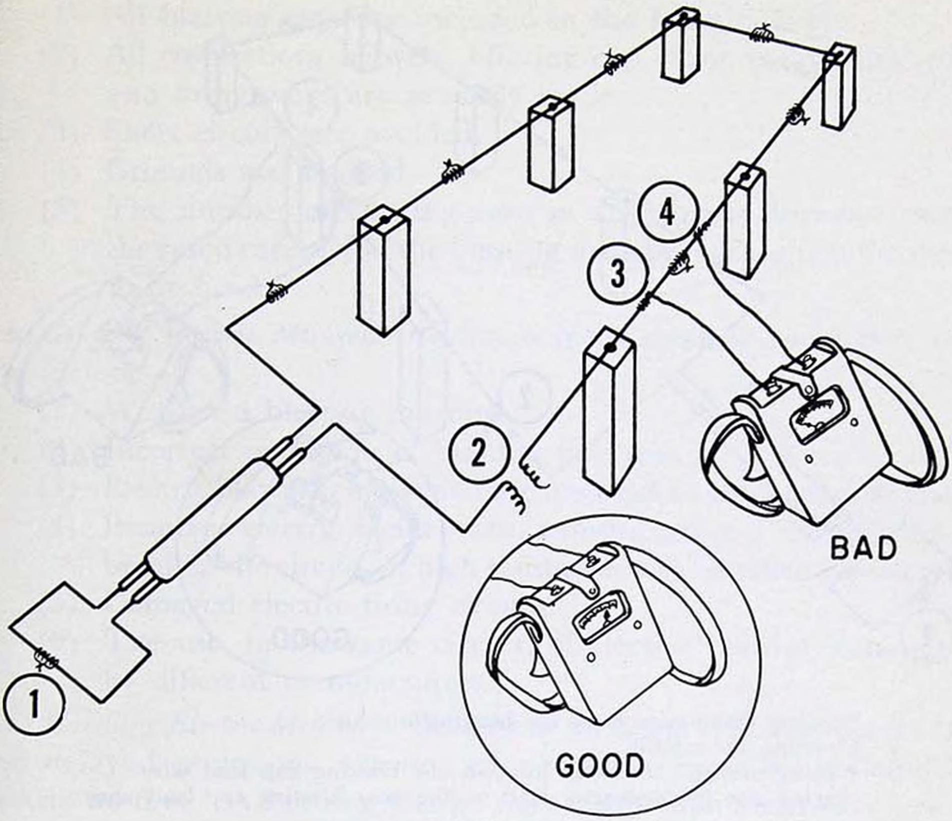
Figure 54. Testing the splices at the end of the firing wire.

92. Locating a Break

If the primer blasting caps have been satisfactorily tested and if a circuit break exists, it can be located in the firing wire or at the splices.

a. Testing the Splices at the End of the Firing Wire.

(1) The firing wire is disconnected from the blasting machine and these two disconnected ends are spliced together (1, fig. 54).
(2) The circuit is opened by disconnecting the splice which joins the first blasting cap lead wire to one firing wire (2, fig. 54).
(3) One lead of the galvanometer is touched to the blasting cap lead wire which has just been disconnected from the firing wire (3, fig. 54).
(4) The other lead of the galvanometer is touched to the blasting cap lead wire just before its splice with the other firing wire (4, fig. 54).
(5) If the galvanometer now registers a current, the break exists at one, or both, of the splices at the end of the firing wire.



1 Splicing firing wires from the blasting machine
2 Opening the circuit
3 Placing one galvanometer lead to one side of splice
4 Placing one galvanometer lead to other side of splice

Figure 55. Testing individual splices.

b. Testing Individual Splices.

(1) Steps *a*(1) and (2) above (1 and 2, fig. 55) are repeated.

(2) One lead wire from the galvanometer is placed on one side of a splice (3, fig. 55), and the other lead wire from the galvanometer is placed on the other side of the splice (4, fig. 55).

(3) The splice is satisfactory if the needle of the galvanometer moves across the scale in the same manner as it did when the galvanometer was tested by short circuiting the terminals.

(4) This test is repeated for each splice until all breaks have been located and corrected.

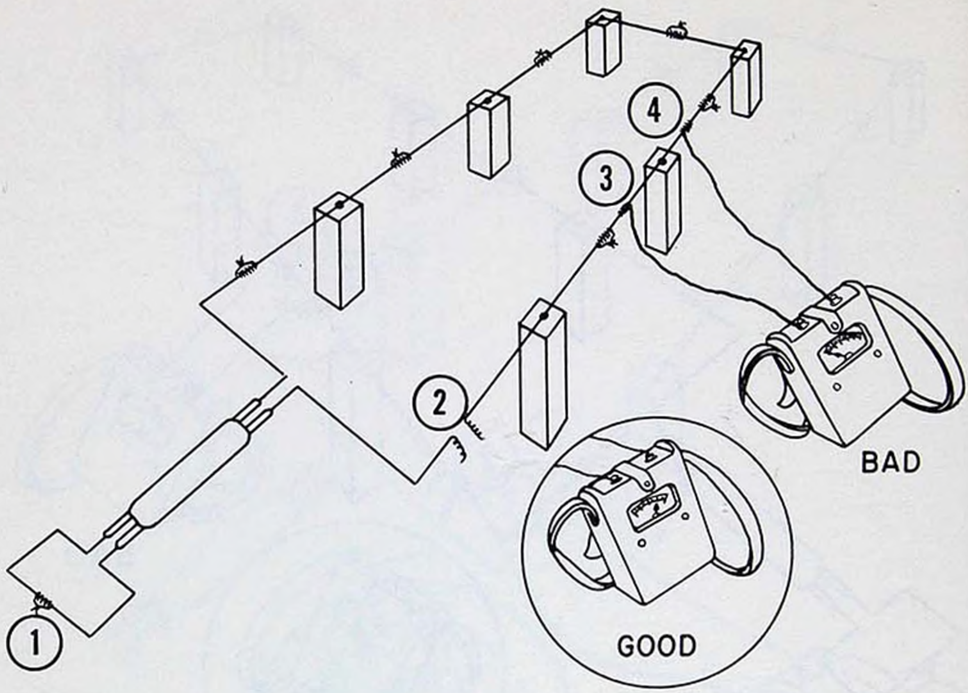
c. Testing Individual Primers (Including Leads to the Primers).

(1) Steps *a*(1) and (2) above (1 and 2, fig. 56) are repeated.

(2) The galvanometer leads are placed across each primer from splice point to next splice point (3 and 4, fig. 56).

(3) Similarly any connecting wires inserted between leads are checked.

(4) Nondeflection of the instrument needle indicates again the existence of a break in that portion of the circuit.



1 Splicing firing wire from the blasting machine
2 Opening the circuit
3 Placing one galvanometer lead on one blasting cap lead wire
4 Placing one galvanometer lead on the next blasting cap lead wire

Figure 56. Testing individual primers.

d. An Alternate Method.

(1) Steps *a*(1) and (2) above are repeated.

(2) One lead from the galvanometer is connected to the blasting cap lead wire which has been disconnected from the one firing wire.

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

(4) The break then occurs somewhere between the point at which the moving lead of the galvanometer is then located and the last point at which the moving lead was located without showing a broken circuit.

e. Repairing the Circuit. If a splice is found to be defective, the wires are to be respliced. If a cap is found to be defective, it is to be treated as a misfire. The entire circuit is to be tested again to make sure all breaks have been found before attempting to fire the charge.

93. Electric Misfires

a. Prevention of Electric Misfires. To prevent misfires, one demolition specialist is to be responsible for all electrical wiring in a demolition circuit. This person is to make all splices to insure 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 with which the shot is to be fired.

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

(1) Weakened blasting machine.

(2) Incorrect operation of blasting machine.

(3) Electric blasting caps which are too weak to detonate 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.

c. Handling Electric Misfires. Because of the hazards of burning charges and delayed explosions, extreme care must be exercised in handling electric misfires. A burning charge may result from electric as well as from nonelectric caps. For handling misfires of charges primed with detonating cord fired by electric blasting caps, see paragraph 105*b*. If the charges are also primed nonelectrically any failure of the electric system to fire should be followed by an attempt to fire the system with the nonelectric primers. This should be done before any misfire procedure is followed. If the charge fails to detonate in a combination dually primed system, a system primed electrically and nonelectrically, it will be necessary to wait 30 minutes before investigating to make certain the charge is not burning. An electric misfire may be investigated immediately provided the cap is above ground and the charge is not dually primed with a nonelectric primer. If the system is below ground and primed only electrically, the recommended procedure is—

(1) The connections of the firing wire to the terminals of the blasting machine are to be checked to be certain that they make good contacts.

(2) Two or three more attempts to fire the circuits are to be made.

(3) The firing wire from the machine is to be disconnected and 30 minutes allowed to elapse before further investigation.

(4) The entire circuit, including the firing wire, is to be checked for breaks or 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—the tamping material is to be removed with great care to avoid striking the electric blasting cap.

(6) No attempt is to be made to remove either the primer or the charge.

(7) If the fault is not located by removing the tamping material to within 1 foot of the charge, a new electric primer and 2 pounds of explosive is to be placed at this point.

(8) The blasting cap wires of the original primer are to be disconnected from the circuit.

(9) The wires of the new primer are to be connected in their place.

(10) The tamping material is to be replaced.

(11) Detonation is to be effected. Detonation of the new primer will detonate the original charge.

Section III. DETONATING-CORD FIRING SYSTEMS

94. General

Detonating-cord firing systems are satisfactory for single or multiple charges. They must be initiated by a blasting cap or other detonator. All branches of the system must be properly connected to prevent failure. These connections may be made with detonating-cord clips or with the knots described in paragraphs 102 and 103. Six inches of free end should be left at all connections or splices to protect the remainder of the cord from moisture.

95. Primers Using Detonating Cord

Since detonating cord must be detonated with a blasting cap, a block of explosive equipped with detonating cord cannot properly be considered a primer. Detonating cord may be used, however, to detonate any number of separate high explosive charges, provided a single electric or nonelectric blasting cap is properly and securely fastened to the cord as described in paragraph 101.

96. Priming TNT and Dynamite with Detonating Cord

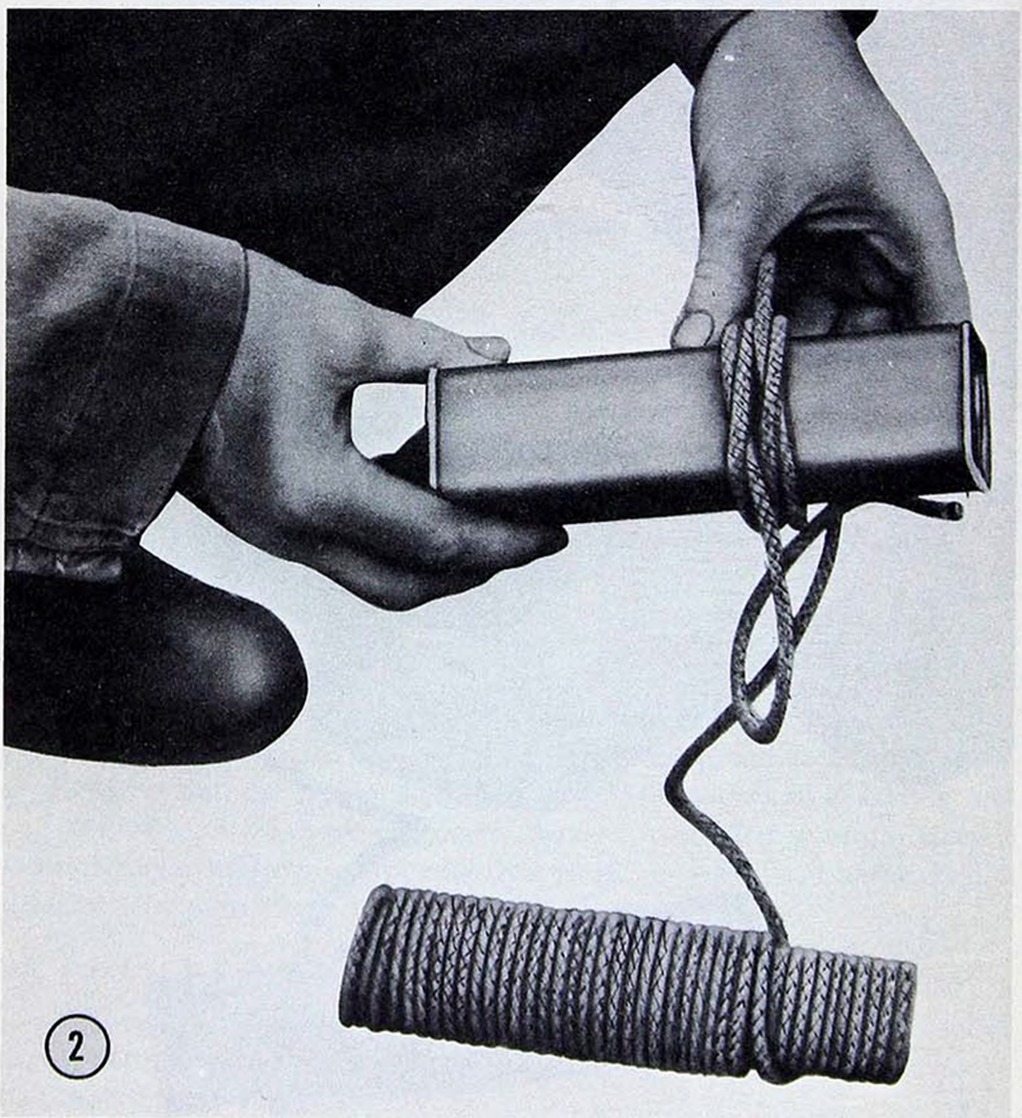
a. When priming adapters are available, explosives containing threaded cap wells are primed with detonating cord to which a nonelectric cap has been attached.

b. When priming adapters are not available or when demolition blocks do not contain threaded cap wells, detonating cord is tied securely around the explosive charge by a clove hitch with an extra turn as shown in 1, figure 57. At least three complete turns are required to insure proper detonation. The cord must fit snugly against the block or cartridge and the loops must be pushed close together (2, fig. 57).

c. When priming dynamite for use in boreholes, ditching, or stumps, the detonating cord must be laced through the dynamite. This is done by punching 2 or 3 holes through the dynamite cartridge and running the detonating cord back and forth through them (3, fig. 57).

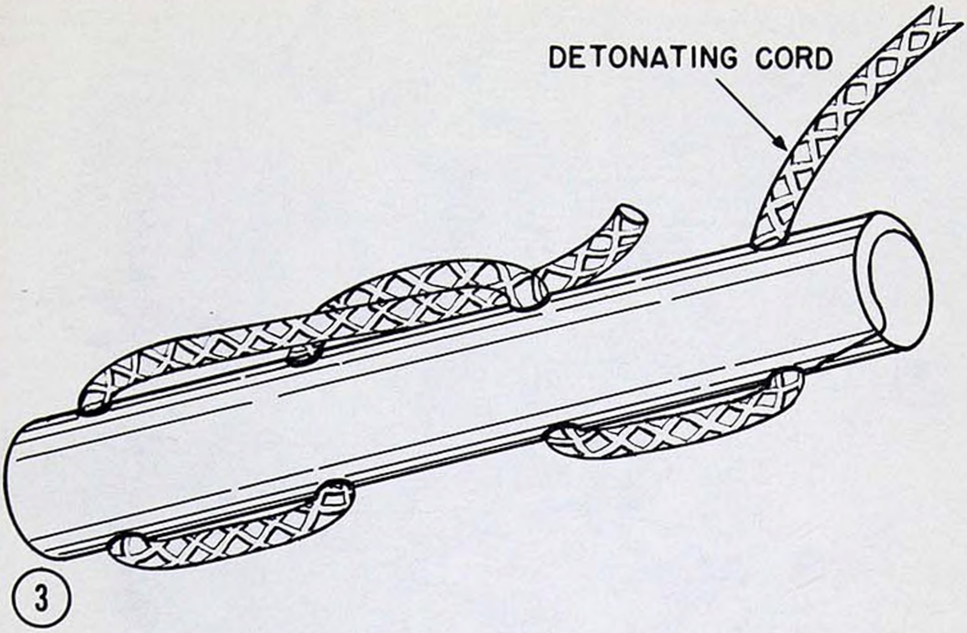
1 Loose loops

Figure 57. Priming TNT block and dynamite with detonating cord.



2 Loops pushed together

Figure 57—Continued.



3 Lacing dynamite

Figure 57—Continued.

97. Priming M1 Chain Demolition Block with Detonating Cord

The M1 chain demolition block is manufactured with detonating cord running through the individual blocks to connect them into a chain. If additional length of 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 of the chain to permit such a connection, the extra length of detonating cord may be affixed by a clove hitch with two extra turns around the end block of the chain.

98. Priming Plastic Explosives (Compositions C3 and C4) with Detonating Cord

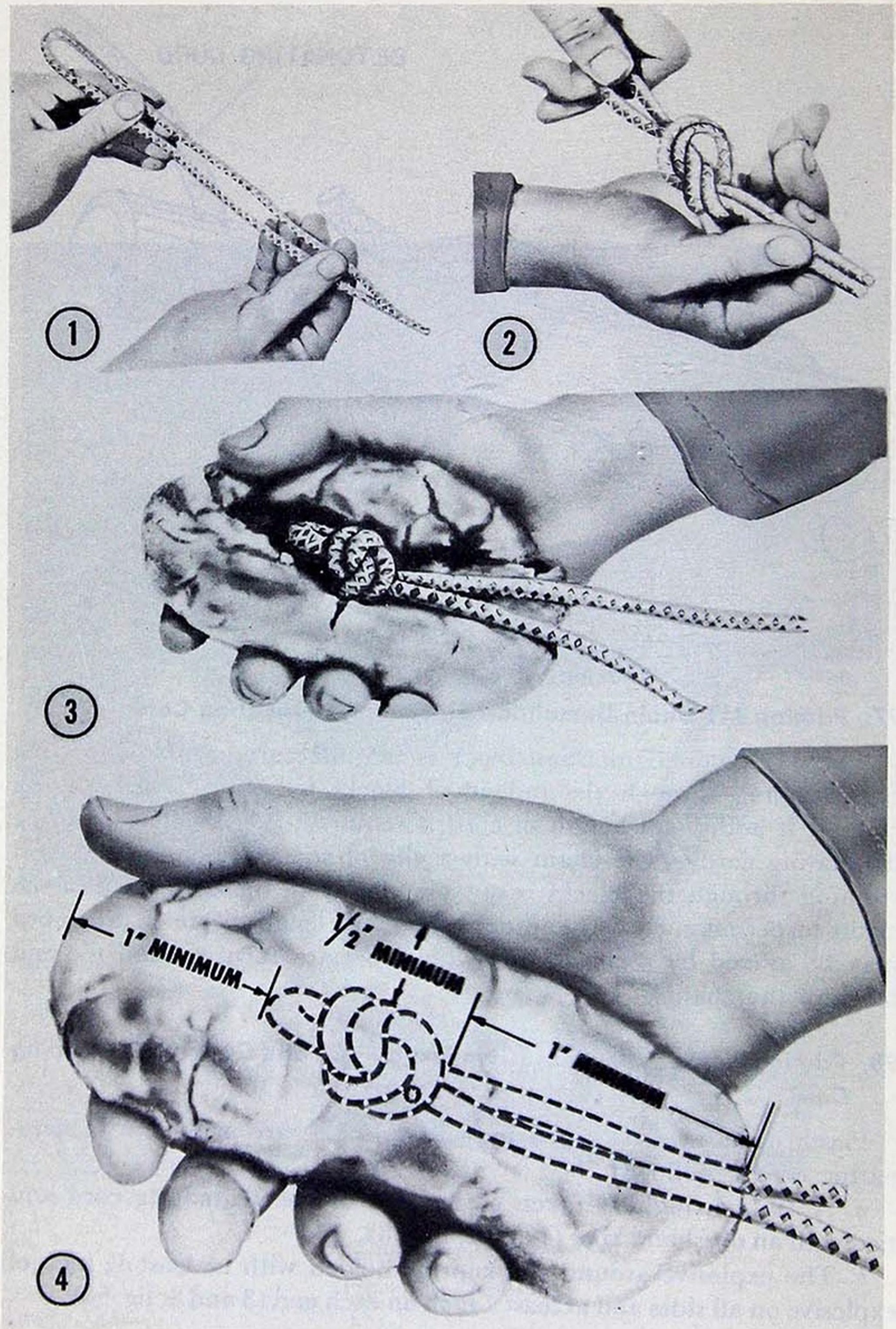
Plastic explosives, Compositions C3 and C4, are primed with detonating cord as follows:

a. A 10-inch bight is taken at the end of the detonating cord and tied with an overhand knot (1 and 2, fig. 58).

b. The explosive around the knot is molded with at least ½ inch of explosive on all sides and at least 1 inch on each end (3 and 4, fig. 58).

99. Priming Ammonium Nitrate Cratering Charge with Detonating Cord

An ammonium nitrate cratering charge is primed with detonating cord by passing the cord through the tunnel on the side of the can and tying a knot 6 inches from the end of the cord (fig. 59).



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

Figure 58. Priming plastic explosive with detonating cord.

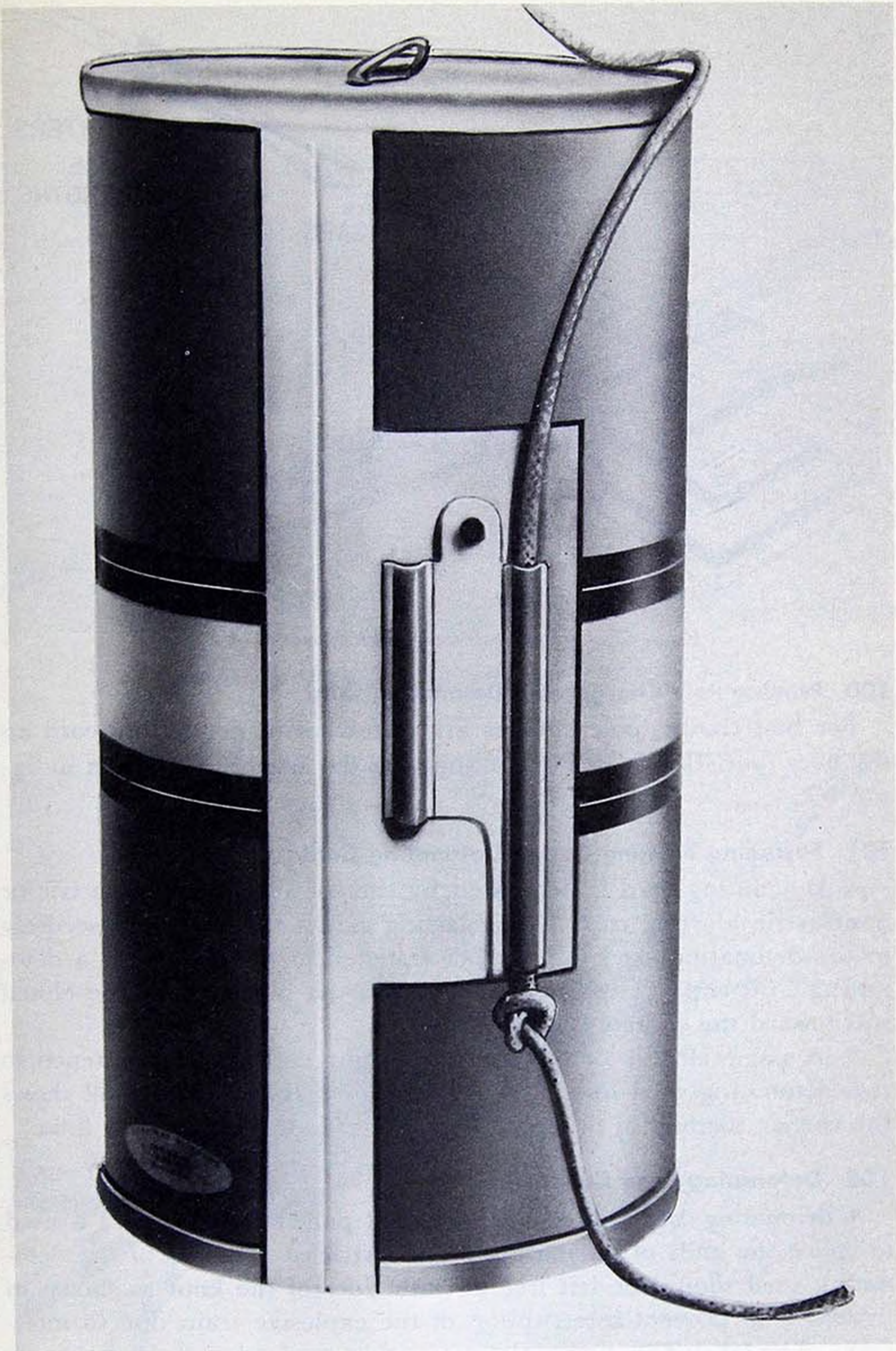


Figure 59. Priming ammonium nitrate cratering charge with detonating cord.

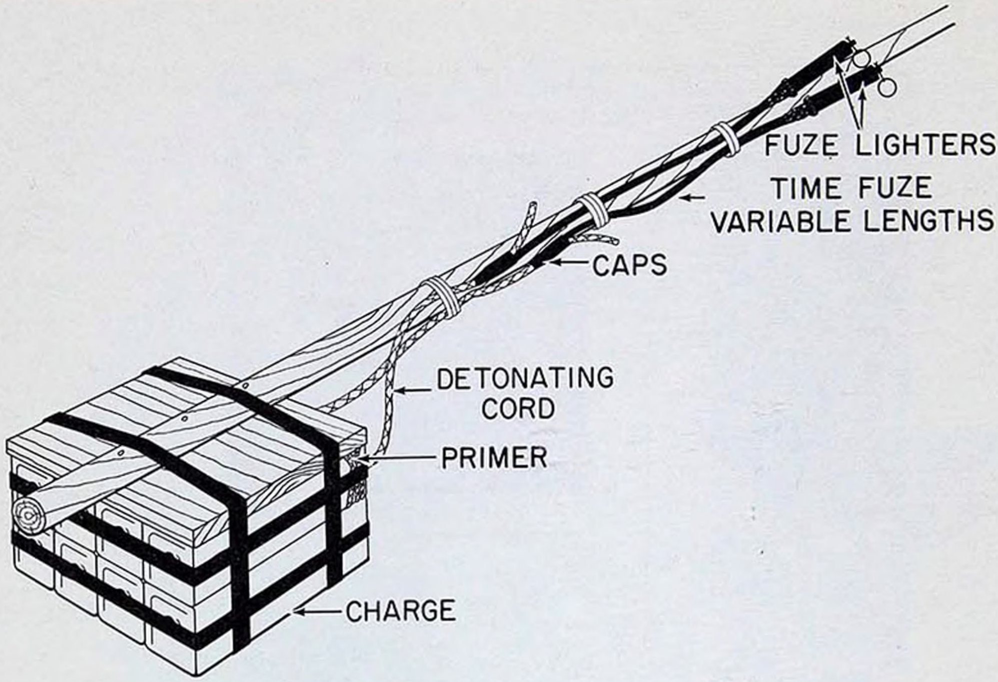


Figure 60. Priming pole charge with detonating cord.

100. Priming Pole Charge with Detonating Cord

For best results, pole charges are primed with detonating cord assemblies (par. 104). Method of applying the assembly is shown in figure 60.

101. Fastening Blasting Cap to Detonating Cord

a. Detonating cord is detonated by the use of either an electric or nonelectric blasting cap. The blasting cap is taped or tied securely to the detonating cord (fig. 61), or fastened to the cord with a detonating-cord clip. The blasting cap must be placed with the closed end toward the charge.

b. A single electric or nonelectric blasting cap properly fastened to two detonating cord lines will detonate both lines. Figure 62 shows the correct method of fastening a cap to two detonating cord lines.

102. Detonating Cord Connections

A detonating-cord clip or a square knot pulled tight (fig. 63) is used to splice the ends of detonating cord. At least 6 inches of the detonating cord should be left free at both sides of the knot as shown in figure 63 to prevent interruption of the explosive train due to moisture. The fabric covering of the detonating cord must not be removed. The knot must not be placed in water nor in the ground unless the charge is to be fired immediately.

103. Branch Line Connection

a. A branch line of detonating cord is fastened to a main line by a detonating cord clip, or by a girth hitch, tied as shown in figure 64.

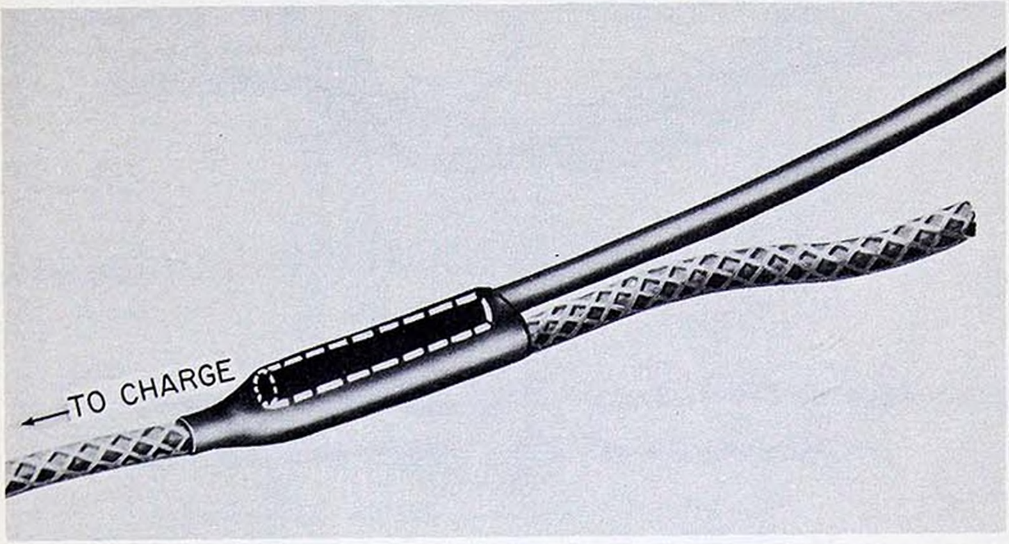


Figure 61. Method of fastening blasting cap to detonating cord.

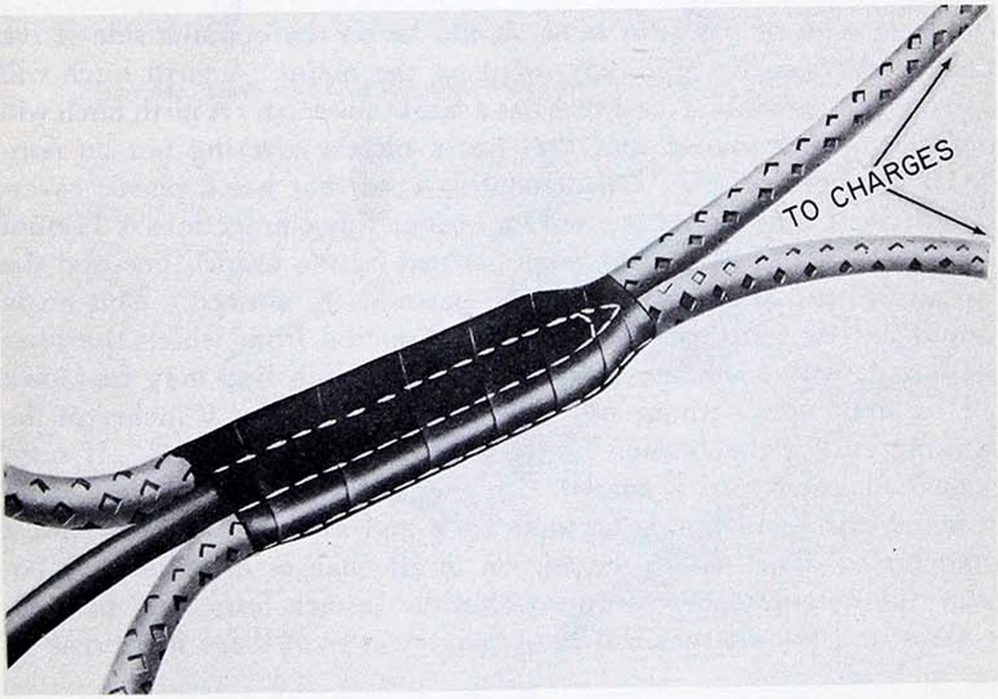


Figure 62. Method of fastening blasting cap to two lines of detonating cord.

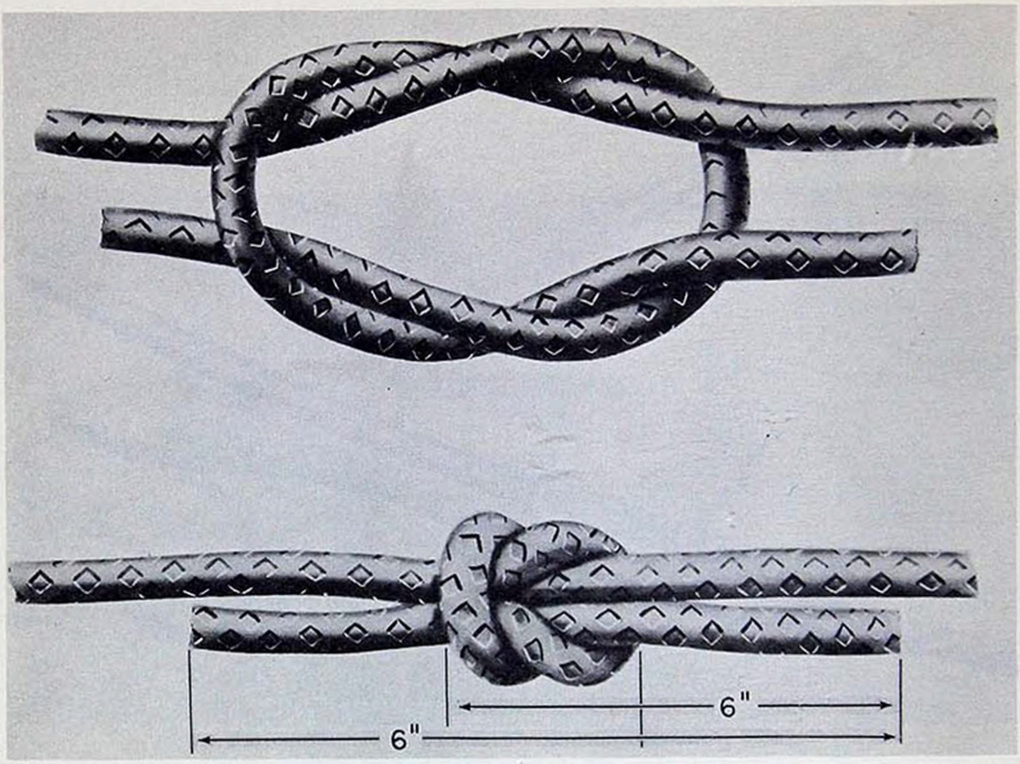


Figure 63. Square knot for connecting ends of detonating cord.

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. A girth hitch will not hold on detonating cord that has a plastic covering nor on reinforced detonating cord. On detonating cord that has a plastic covering, the knot that should be used for branch line connections is 3 round turns and a half hitch. The angle formed by the branch line and the cap end of the main line should be particularly noticed. This angle should not be less than 90° from the direction from which the blast is coming; with a smaller angle here, 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. 65) 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 if there is a break in the main line.

b. Any number of branch lines may be connected to the main line at any one point. However, a branch line is never connected at a point where the main line is spliced.

c. In making branch line connections, precautions should be taken to insure that detonating cords do not touch in places where they cross. If

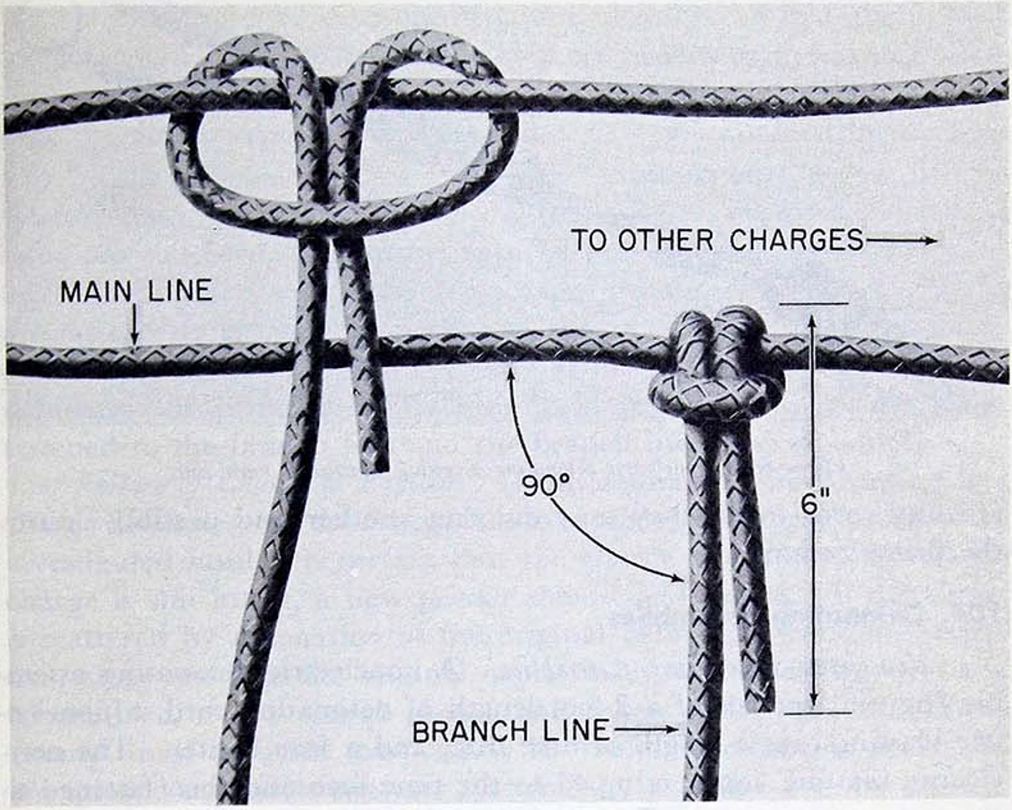


Figure 64. Girth hitch used to connect branch line to main line of detonating cord.

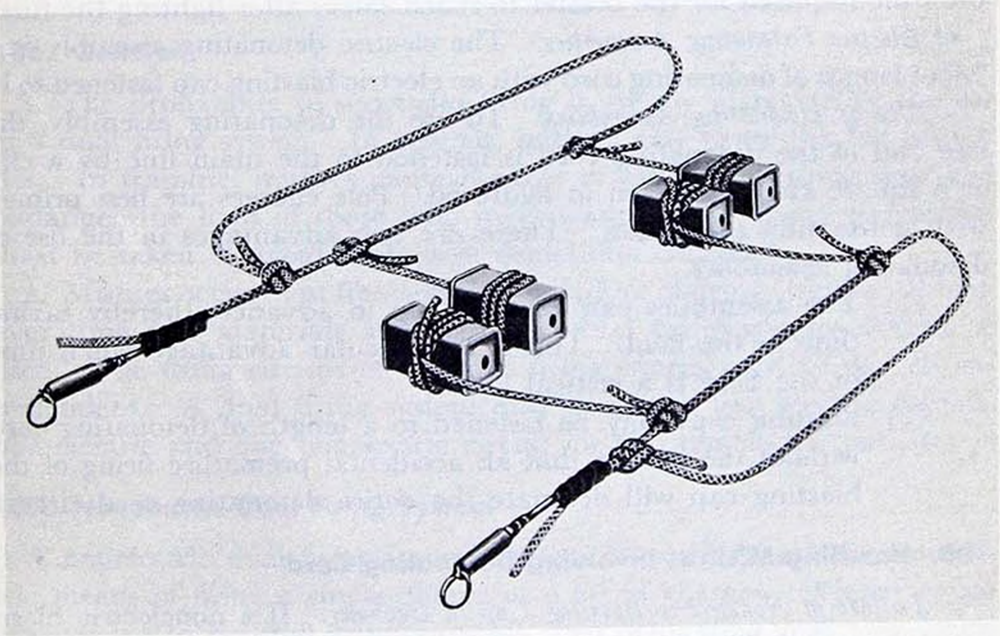


Figure 65. Nonelectric dual firing system utilizing two ring mains to fire a set of charges simultaneously.

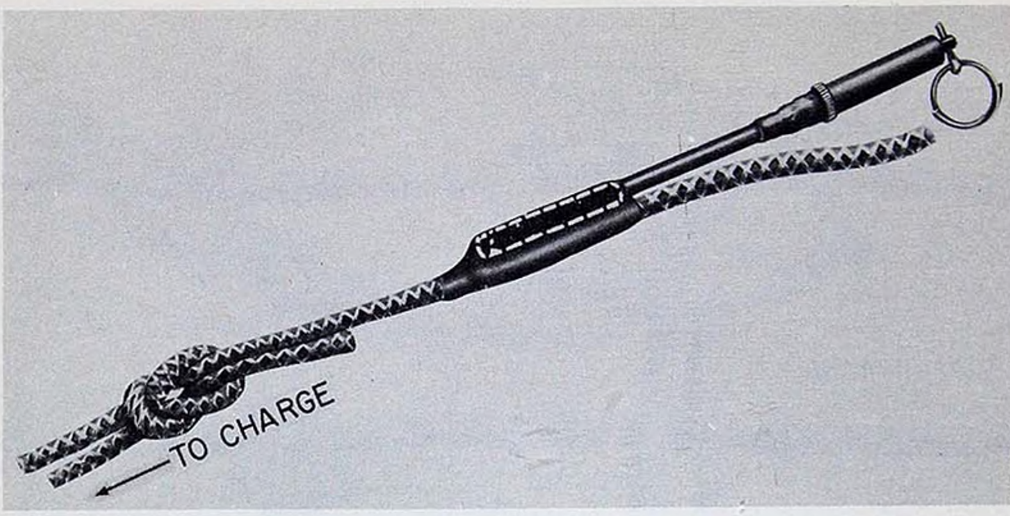


Figure 66. Nonelectric detonating assembly attached to main line.

crossing cords touch they may cut one another and possibly destroy the firing system.

104. Detonating Assemblies

a. Nonelectric Detonating Assemblies. A nonelectric detonating assembly (fig. 66) consists of a 2-foot length of detonating cord, a nonelectric blasting cap, a length of time fuze, and a fuze lighter. The nonelectric blasting cap is crimped to the time fuze and then fastened to the detonating cord. The fuze lighter is then attached to the end of the time fuze. The length of the time fuze that is needed depends on the time required for the blaster to reach safety after lighting the fuze.

b. Electric Detonating Assemblies. The electric detonating assembly is a 2-foot length of detonating cord with an electric blasting cap fastened to it.

c. Use of Detonating Assemblies. To use the detonating assembly, the free end of the detonating cord is fastened to the main line by a clip or a square knot, as shown in figure 66. Pole charges are best primed with detonating assemblies. There are two advantages in the use of detonating assemblies.

(1) The assemblies can be made up in advance, thereby saving time in the field. This is a particular advantage when time in the field is a critical factor.

(2) Blasting caps may be fastened to a length of detonating cord without the danger that an accidental premature firing of the blasting cap will detonate the entire detonating cord circuit.

105. Handling Misfires Involving Detonating Cord

a. Failure of Nonelectric Blasting Cap to Detonate. If a nonelectric blasting cap used to fire detonating cord fails to detonate, investigation of the misfire should be delayed for at least 30 minutes. Then the detonating cord main line between the blasting cap and the charge should be cut and a new blasting cap should be fastened to the detonating cord.

b. Failure of Electric Blasting Cap to Detonate. If an exposed electric blasting cap, used to fire detonating cord, fails to detonate, the blasting circuit should be disconnected immediately and investigated. A search should be made for breaks or short circuits in the electric firing circuit (par. 89). If necessary, the electric blasting cap should be removed from the detonating cord and a new one fastened in its place.

c. Failure of Detonating Cord to Detonate. If an exposed electric or nonelectric blasting cap, used to fire detonating cord, explodes but fails to detonate the cord, the failure may be investigated immediately. A new blasting cap should be fastened to the detonating cord, taking special care to fasten it properly.

d. Failure of Branch Line to Detonate. If the detonating cord main line detonates but a branch line fails to detonate, a blasting cap should be fastened to the branch line and the branch line fired separately.

e. Failure of Charge to Explode. If the detonating cord leading to a charge detonates, but the charge fails to explode, the failure should not be investigated until it is certain that the charge is not burning. If the charge is still intact, a new primer should be inserted. If the charge is scattered by detonation of the original detonating cord, the explosive, or as much of the original explosive as is practicable, should be reassembled, a new charge placed, and a new primer inserted. Every attempt must be made, particularly in training exercises, to recover all unexploded explosives that are scattered by a misfire.

Section IV. DUAL FIRING SYSTEMS

106. General

a. The probability of successful firing is greatly increased by the use of a dual firing system. In combat, misfires may cause the loss of battles. In training, misfires cause the loss of valuable training time and endanger the lives of those who investigate them. Every precaution must be taken to avoid misfires of demolition charges.

b. Misfires occur most frequently from failure of firing circuits. Whenever time and materials are available, dual firing systems should be used. The firing circuits of the dual firing system must be entirely independent. A dual firing system may consist of two electric circuits, one electric and one nonelectric circuit, or two nonelectric circuits.

107. Nonelectric Dual Firing System

A nonelectric dual firing system consists of two independent nonelectric means of firing a single charge or a set of charges. Where several charges are to be fired simultaneously, two detonating cord ring mains are laid out, and a branch line from each is run to a nonelectric blasting cap in each charge. Figures 65 and 67 show methods of layout for nonelectric dual firing systems.

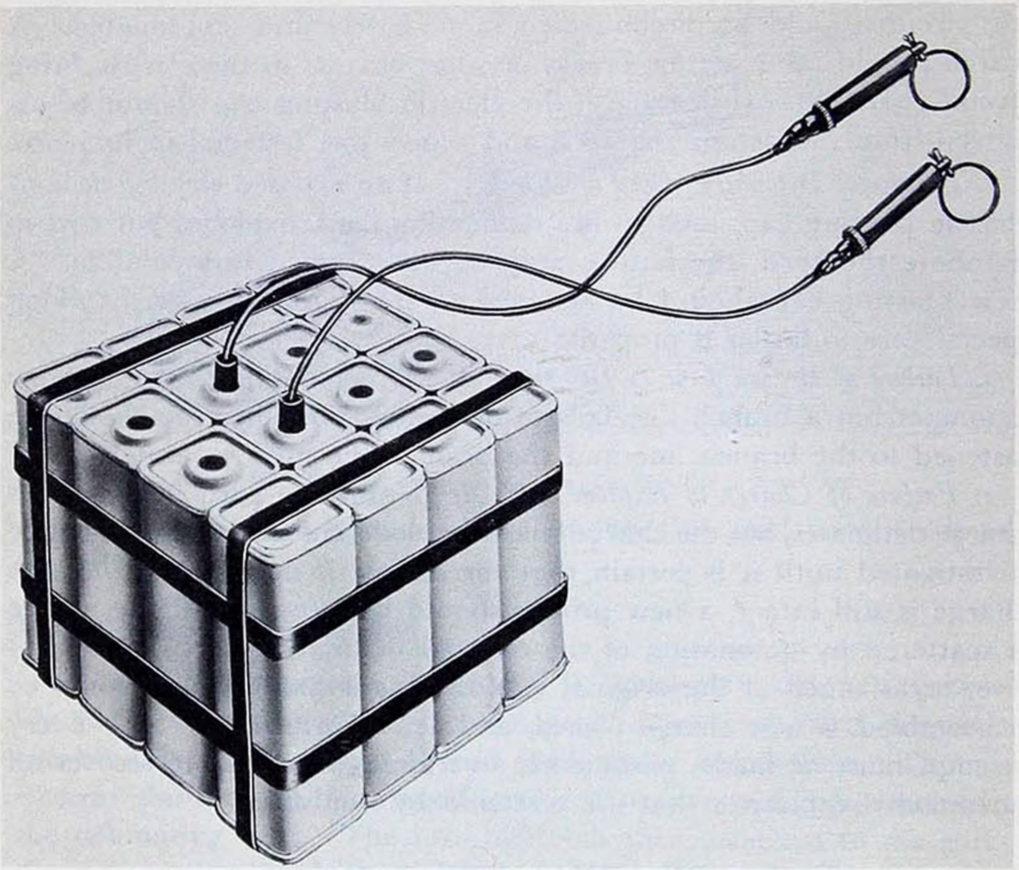


Figure 67. Nonelectric dual firing system for a single charge.

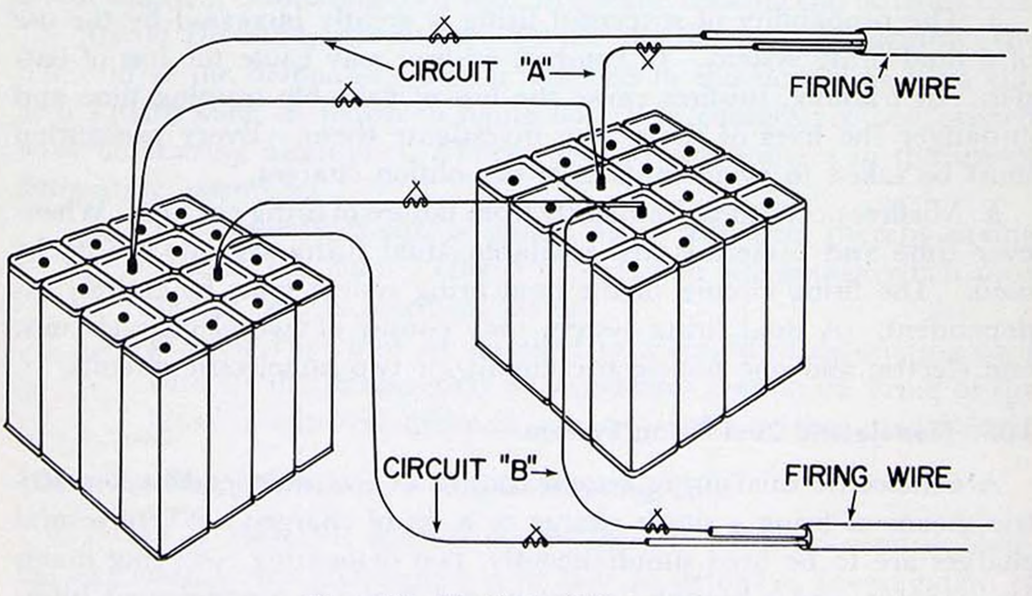


Figure 68. Electric dual firing system.

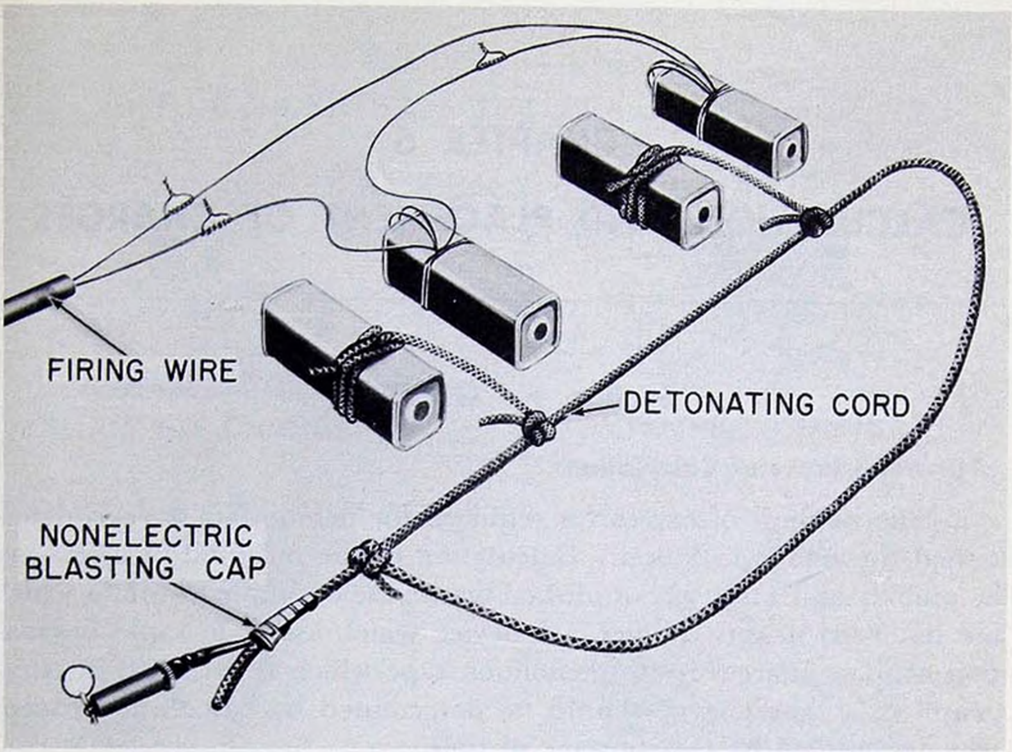


Figure 69. Combination dual firing system.

108. Electric Dual Firing System

An electric dual firing system consists of two independent electric firing circuits. Each circuit must include an electric blasting cap in each charge, so that firing either circuit will detonate all charges; thus each charge must contain two electric primers. The correct method of layout for an electric dual firing system is shown in figure 68. The firing wires of the two circuits should be kept separated so that both will not be cut by a single bullet nor a single shell fragment.

109. Combination Dual Firing System

A combination dual firing system provides an electric means and a nonelectric means of firing charges. Each charge contains both an electric primer and a nonelectric primer, made with a blasting cap or detonating cord. Multiple charges to be fired simultaneously by nonelectric primers must have the nonelectric primers made with detonating cord. The electric and nonelectric firing circuits must be entirely independent of each other. The nonelectric firing system should be fired first. The correct method of layout for a combination dual firing system is shown in figure 69.

CHAPTER 6

CALCULATION AND PLACEMENT OF CHARGES

Section I. GENERAL

110. Importance of Calculation

a. The amount of explosives required for demolition work is determined through calculation. Calculation of the required charges may be quickly and easily accomplished by the use of simple formulas which are discussed in this chapter. A device which assists in rapid calculation of these charges is the demolition tape which is discussed in paragraph 62. The charge should be determined by calculation except when prevented by the shortage of time.

b. The value obtained for *P* from use of the formula discussed later represents the amount of TNT (in pounds) required for a charge. When other explosives are used, the value of *P* must be adjusted in accordance with the strength of these other explosives relative to TNT, but only when external charges are computed from one of the following formulas:

(1) Steel cutting formula.
(2) Timber cutting formula.
(3) Breaching formula.
(4) Pressure formula.

Column 4 of table I shows the relative strength factors of other explosives. The necessary adjustment is accomplished by dividing the *P*-value obtained for TNT by the relative strength factor for the explosive to be used. An example of this adjustment is given in paragraph 114*f*. Steel and timber charges are usually small in size, but should be adjusted when possible, as indicated above.

111. Tamping of Explosive Charges

a. As explained in paragraphs 4 and 5 the force and effect of an explosion depends on the type and quantity of explosives involved. The destructive effect depends on the contact between the explosive and the target and the manner in which the explosive force is directed at the target.

b. When an explosive is detonated, it exerts pressure in all directions. Therefore, an explosive sealed tightly inside an object to be destroyed exerts force on the material all around it and produces the

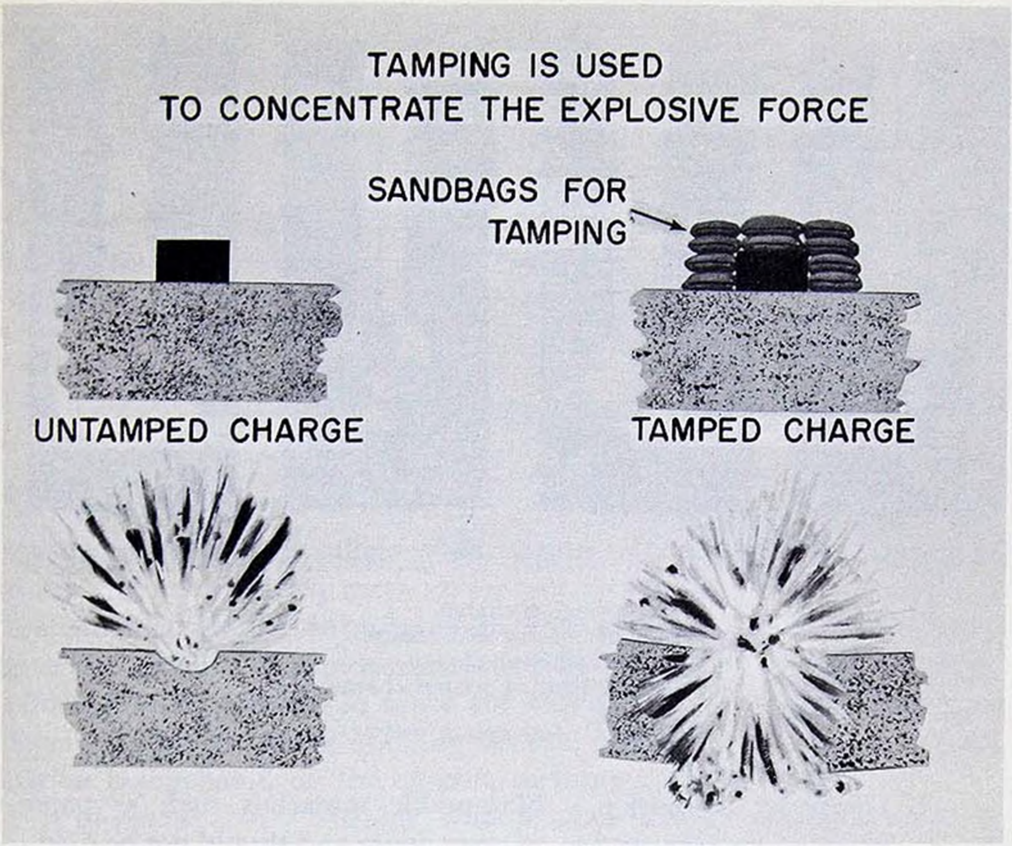
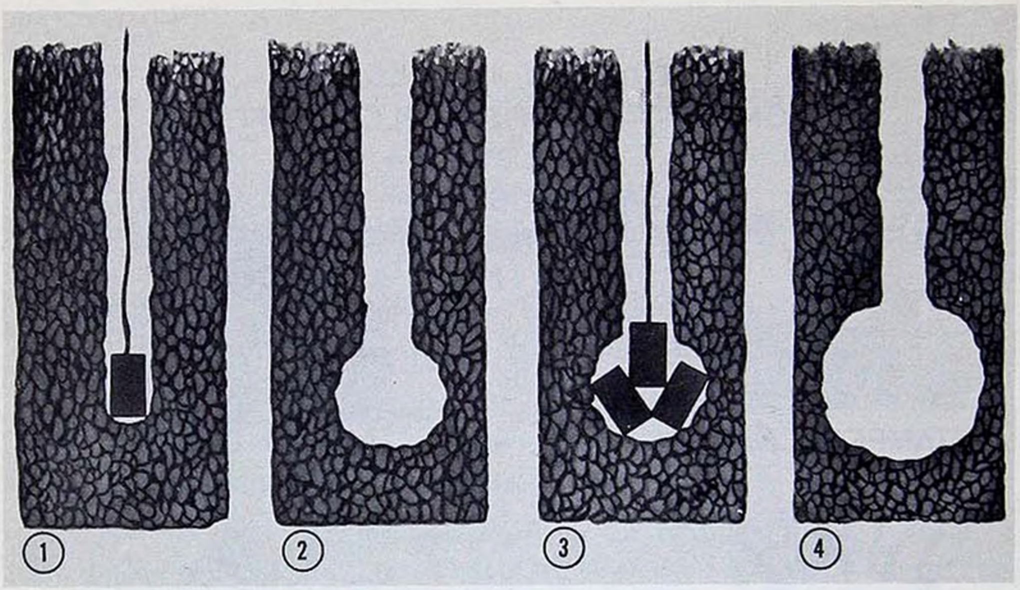


Figure 70. Confinement of explosives.

maximum destructive effect. However, if the explosive is not completely sealed in, some explosive pressure escapes through the openings and part of the destructive effect is lost. Also, if the material surrounding the explosive is not equally strong on all sides, the force breaks through the weakest spot first. To obtain maximum effectiveness, explosive forces must be confined in some manner. These principles are illustrated in figure 70.

c. The confinement of the explosive forces is obtained by packing material around the charge. This operation is known as tamping the charge. The material used for covering the charge is called the tamping material or tamping. In a deep borehole the material which is packed in the hole on top of the charge is called stemming and the borehole is said to be stemmed. Explosive forces are tamped by one of the following methods.

(1) Internal charges are confined by tightly packing earth, sand, clay, or other dense material into the opening of the hole containing the explosive. This material (stemming) is tamped and packed against the explosive and fills the hole all the way to the collar. In drill holes this stemming should not be tamped until the explosive is covered by at least one foot of the material. Light materials should not be used for stemming since they are apt to blow out of the borehole and cause in-



1 First springing charge
2 After detonating first charge
3 Second springing charge
4 After detonating second charge

Figure 71. Springing a borehole.

complete detonation. Flammable materials such as paper, sawdust, sacking, and so on, may ignite and should not be used.

(2) External charges are tamped by covering them with tightly packed sand, clay, or other dense material. The tamping material may be contained in sandbags or may be loose. For maximum effectiveness, the thickness of the tamping should at least equal the breaching radius (par. 125). Small breaching charges on the horizontal surfaces are sometimes tamped by placing several inches of thick, heavy clay or mud around the charge. This method of tamping is called mud-capping.

112. Use of Springing Charges

a. General. After drilling to a desired depth with hand-operated or mechanized earth augers, a small springing charge is fired at the bottom of the borehole to form a chamber in which a larger charge may be placed. Two or more springing charges in succession may be needed to make a chamber large enough to hold the final charge. The number and size of springing charges is determined by experiment because the chamber formed by a given amount of explosive varies with the type of soil. One method of springing a borehole with 2 charges is shown in figure 71. At least 30 minutes must be allowed for the borehole to cool between firing and placing successive charges, and more time will be required in some materials or with larger charges unless cooling is hastened by placing water in the hole.

b. Using Detonation Cord. Three or four strands of detonating cord extending the full length of the borehole and fired simultaneously with the springing charge will enlarge the borehole and facilitate inserting subsequent charges.

c. Limitations by Soil Types. The methods of enlarging boreholes described in *a* and *b* above are suitable only in hard soil that stands readily by itself. The method outlined in *b* above is used only if earth augers for drilling large diameter boreholes are not available or if the soil is too hard for the successful use of earth augers.

Section II. STEEL-CUTTING CHARGES

113. General

Steel parts and members often require cutting in demolition operations. Quick and easy methods for calculating the steel-cutting charges are provided by the formulas given in paragraph 114. These formulas give the amount of explosive required for untamped charges, but every effort should be made to tamp the charges for increased effectiveness. Steel in general can be roughly divided into three classes, this classification being based on the carbon, or other content of the steel.

a. Structural Steel. I-beams, wide-flanged beams, channels, angle sections, structural tees, and steel plates used in building or bridge construction are examples of products made from this grade of steel. This is the grade of steel which will most frequently be encountered because it is the steel with which buildings, bridges, and other steel structures are built. The formula given in paragraph 114*a* is applicable to this grade of steel except in the cases of slender structural bars (such as concrete reinforcing bars), where the difficulty in effectively placing the charge makes the formula given in paragraph 114*b* the proper one to use.

b. High-Carbon Steel. This grade of steel is usually used for such parts as metal-working dies and rolls. The formula in paragraph 114*b* is applicable to this steel.

c. Alloy Steel. Items such as gears, shafts, tools, and plowshares are now usually made from alloy steel. Chains and cables are usually made from either a high-carbon steel or an alloy steel. The formula given in paragraph 114*b* applies to alloy steel.

114. Calculation of Charges

a. Formula for Structural Steel Sections. Charges to demolish I-beams, built-up girders, steel plates, columns and other structural steel sections are computed by a formula, as follows:

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

where: P = pounds of TNT required, and
A = cross-sectional area, in square inches, of the steel member to be cut.

b. Formula for Other Steel Structures. The following formula is recommended for computing the cutting charge needed for high-carbon steel parts or for alloy steel articles. This formula is also used for structural steel bars, such as concrete-reinforcing bars, where the small size makes good charge placement difficult or impossible. This formula is used for chains, cables, reinforcing bars, strong forgings, steel rods, machine parts, and high-strength tools.

$$P = D^2$$

where: P = pounds of TNT
D = diameter in inches of section to be cut.

c. Railroad Rails. The size of a railroad rail is usually expressed in terms of the weight of 1 yard of the rail. Thus an 80-pound rail is one which weighs 80 pounds per yard. The proper charge to cut an 80-pound or lighter rail is ½ pound of TNT placed against the web.

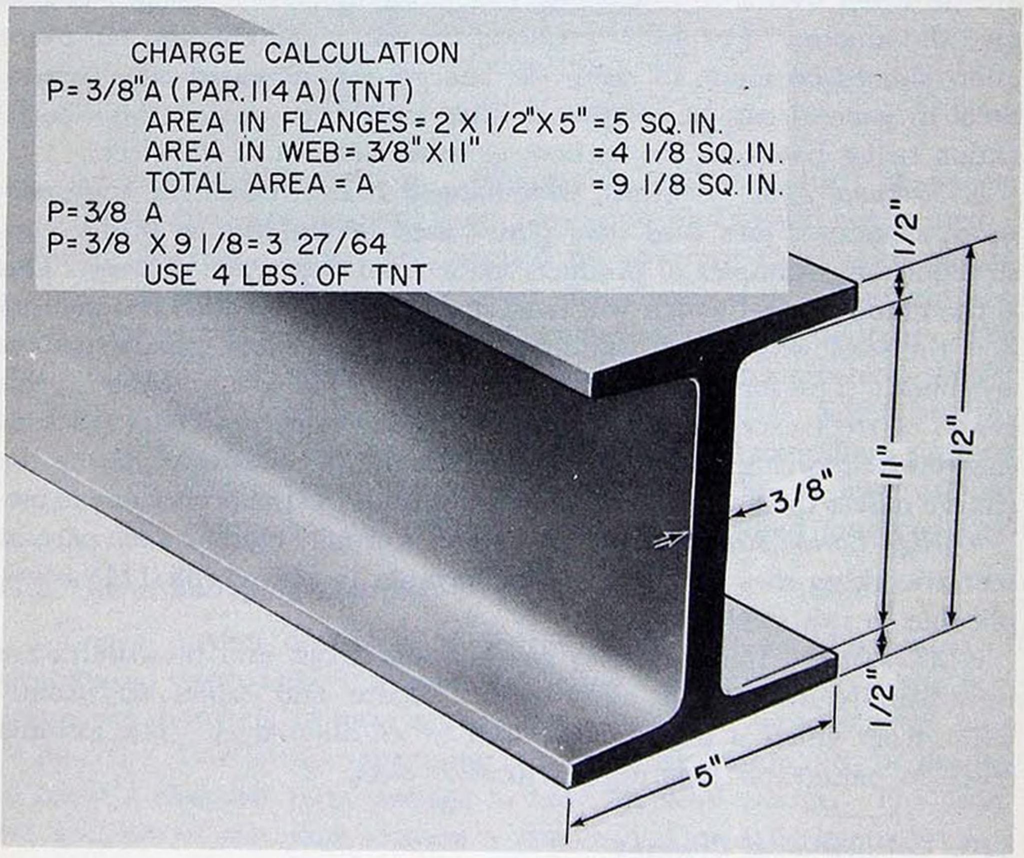


Figure 72. Calculation of charge for cutting steel I-*beam.*

The proper charge for a heavier railroad rail is 1 pound of TNT placed against the web of the rail. As a general rule, rails which measure more than 5 inches from the bottom of the base to the top of the head weigh more than 80 pounds per yard.

d. "Rounding-Off" Rule. The charges calculated from the above formulas and from other similar formulas in the text should be rounded off to the next higher unit package of the explosive being used. If, for example, calculations indicate that $3\frac{27}{64}$ pounds of explosive is required, 4 pounds is the correct amount of TNT to use. This rounding off rule will, however, require discretion. If only ½-pound charge is required and only 2½-pound blocks are available, the block probably would be cut into quarters and only one quarter used.

e. Illustrative Problem: Cutting Steel I-Beam. How much TNT is required to cut the steel I-beam shown in figure 72? The solution to this problem is given in figure 72.

f. Illustrative Problem: Explosive Other than TNT and Composition C4. How

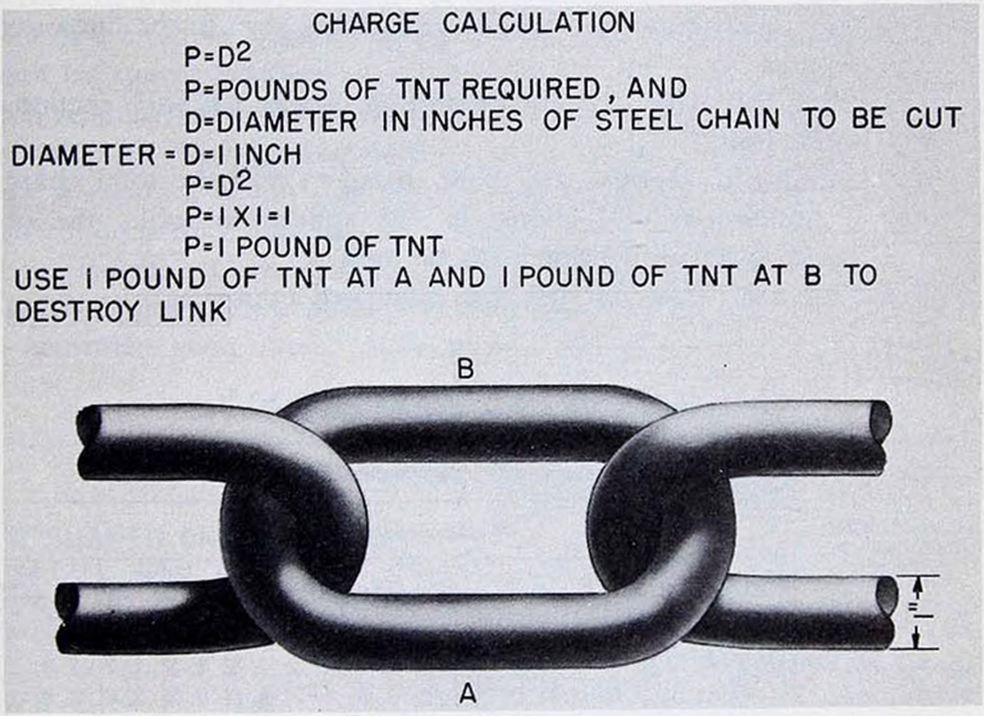


Figure 73. Calculation of charge to cut steel chain.

much 60 percent straight dynamite is required to cut the steel I-beam shown in figure 72?

Amount of TNT required (from fig. 72) $= 3\frac{27}{64}$, or, 219/64 pounds;
60% straight dynamite is 0.83 times as effective as TNT (from column 4 of table I).

$$P \text{ (of 60\% straight dynamite)} = \frac{219/64}{0.83} = 4\tfrac{1}{8} \text{ pounds.}$$

Use 9 (or possibly 8½) ½-pound sticks of 60 percent straight dynamite.

g. Illustrative Problem: Cutting Steel Chain. How much TNT is required to cut the steel chain shown in figure 73? The solution to this problem is given in figure 73. Notice that the link should be cut in two places (once on each side rail of the link) to effect a complete failure of the chain.

h. Use of Table in Making Calculations. Table VIII gives the correct weight of TNT necessary to cut steel sections of various dimensions. This table was calculated from the formula $P = \frac{3}{8}A$. In using this table:

(1) The rectangular sections of members are to be measured separately.
(2) Using the table, the corresponding charge for each section is to be found.
(3) Charges for sections are to be found to find the total charge.
(4) If dimensions of sections do not appear in table, the next larger given dimension is to be used.

Caution: Never use less than calculated amount.

Table VIII. Steel Cutting Charges

Pounds of explosive* for rectangular steel sections of given dimensions

Average thickness of sections in inches	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.

i. Problem. For example, the problem given in paragraph 114 and figure 72 can be solved as follows:

Charge for flanges:	Charge for web:
width = 5 inches	width = 11 inches
thickness = ½ inch	thickness = ⅜ inches
Charge from table = 1.0 pounds flange	Charge from table = 1.6 pounds

Total charge 2 flanges = 2×1.0 = 2. 0 pounds
web = 1×1.6 = 1. 6 pounds
3. 6 pounds

Use 4 pounds of TNT

115. Placement of Charges

a. Steel Sections. The size and type of a steel section dictate the placement of explosive charges. Some elongated sections may be cut by placing the explosive on one side of the section completely along the desired 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, the individual members are fabricated from two or more primary sections, such as angle irons or bars, separated by spacer washers or gusset plates. Generally, the charge on such sections 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. 74). Heavier H-beams, wide flange beams, and columns may also require auxiliary charges placed on the outside of the flanges. Care should be taken that opposing charges are never directly opposite each other. If they are directly opposite, they tend to neutralize each other. Whenever a charge is separated, each por-

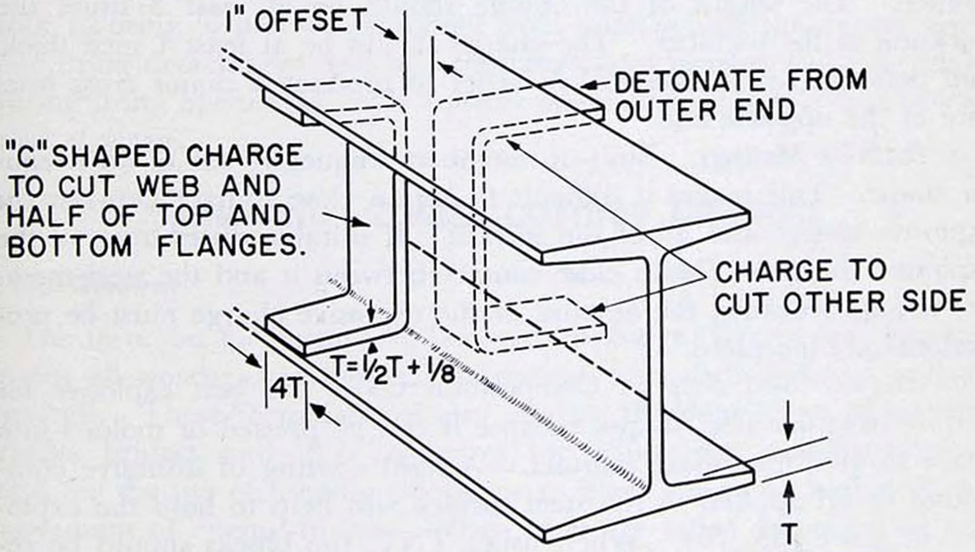


Figure 74. Explosive staggered on opposite sides of steel member to give a shearing effect.

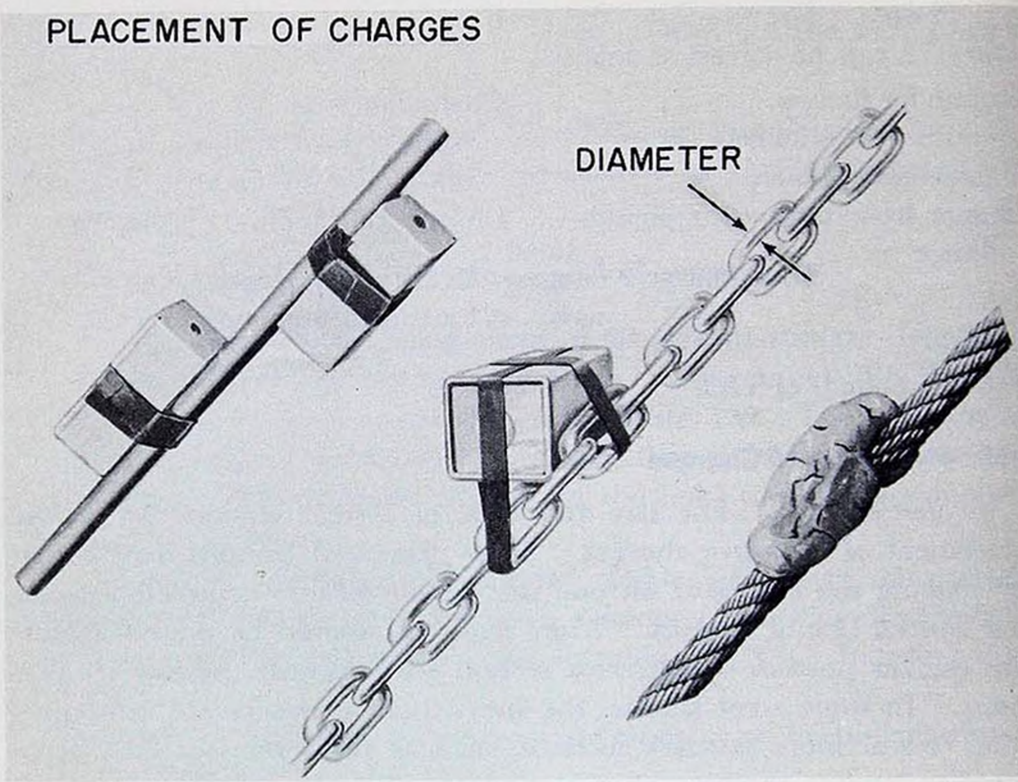


Figure 75. Proper placement of charges to cut rods, cables, and chains.

tion must be primed, and all primers must be connected with detonating cord for simultaneous firing.

b. Rods, Chains, and Cables. When cutting steel rods, chains, and cables (fig. 75) TNT is not recommended if Composition C4 is available. Composition C4 should be placed on only one side of the member to be cut, the width of the charge slightly less than ½ the circumference. The length of the charge should be at least 3 times the thickness of the member. The charge should be at least 1 inch thick, and detonated from one end in order to produce a major cross fracture at the opposite end.

c. Built-Up Members. Built-up members frequently are of an irregular shape. This makes it difficult to obtain close contact between the explosive charge and all of the surface. If suitable distribution of the explosive charge to obtain close contact between it and the steel member is impracticable, the amount of the explosive charge must be proportionately increased.

d. Irregular Steel Shapes. Composition C4 is the best explosive for cutting irregular steel shapes because it can be pressed or molded into place to give maximum contact. A light coating of adhesive compound or oil applied to the steel surface will help to hold the explosive in place (fig. 76). When using TNT, the blocks should be removed from their containers. In addition, mud or grease should be used to fill in any air gaps between separate blocks and between the blocks and the steel.

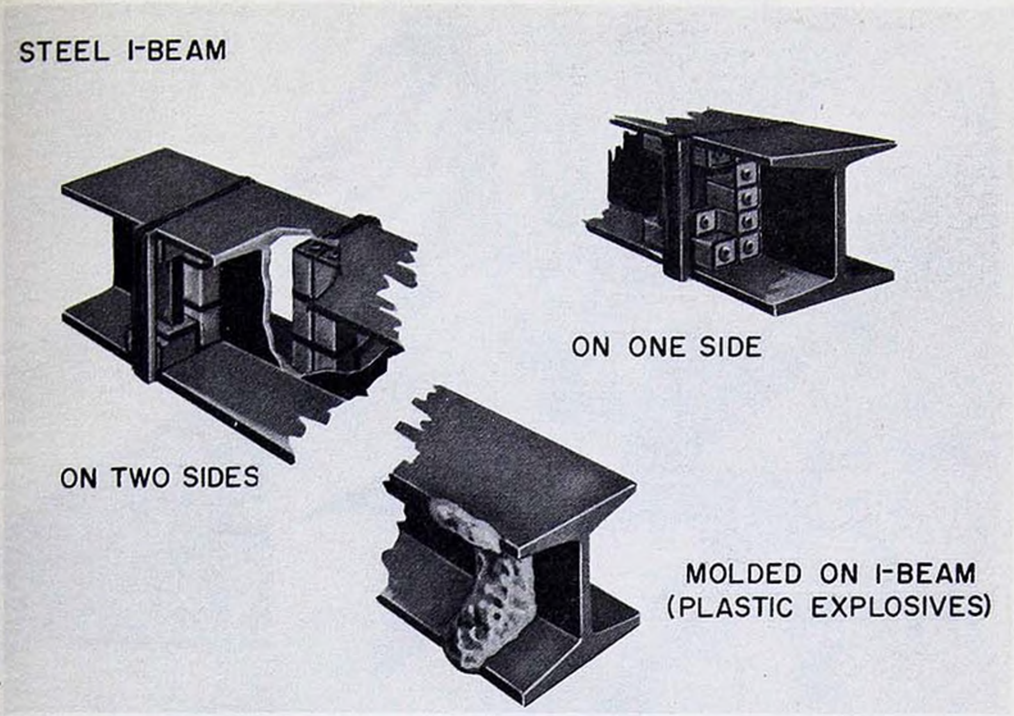


Figure 76. Placement of solid and plastic charges to cut steel I-*beam.*

e. Securing Explosives in Place. All explosives must be tied, taped, or wedged in place (fig. 77) unless they rest on horizontal surfaces and are not in danger of being jarred out of place.

116. Precautions

When used to cut steel, explosive charges throw steel fragments (missiles) long distances at high velocities. Guards should be posted prior to firing to prevent personnel from approaching the danger area. The firing detachment and all other personnel nearby *must* take cover during firing operations. *The explosive charge must not be fired until everyone is out of danger.*

Section III. TIMBER-CUTTING CHARGES

117. General

The formulas for cutting timber with explosive charges are designed to cut all woods; even tropical hardwoods and such fibrous woods as coconut. These formulas are also used in the demolition of wooden trestles, bridges, and other structures, for felling trees in order to clear land for the use of friendly troops, or to block roadways and slow the movement of enemy forces. When trees are felled to create an obstacle it is desirable to leave the trees attached to the stumps by making an incomplete cut. This is accomplished by a different charge calculation and a different placement of the explosive charge than that

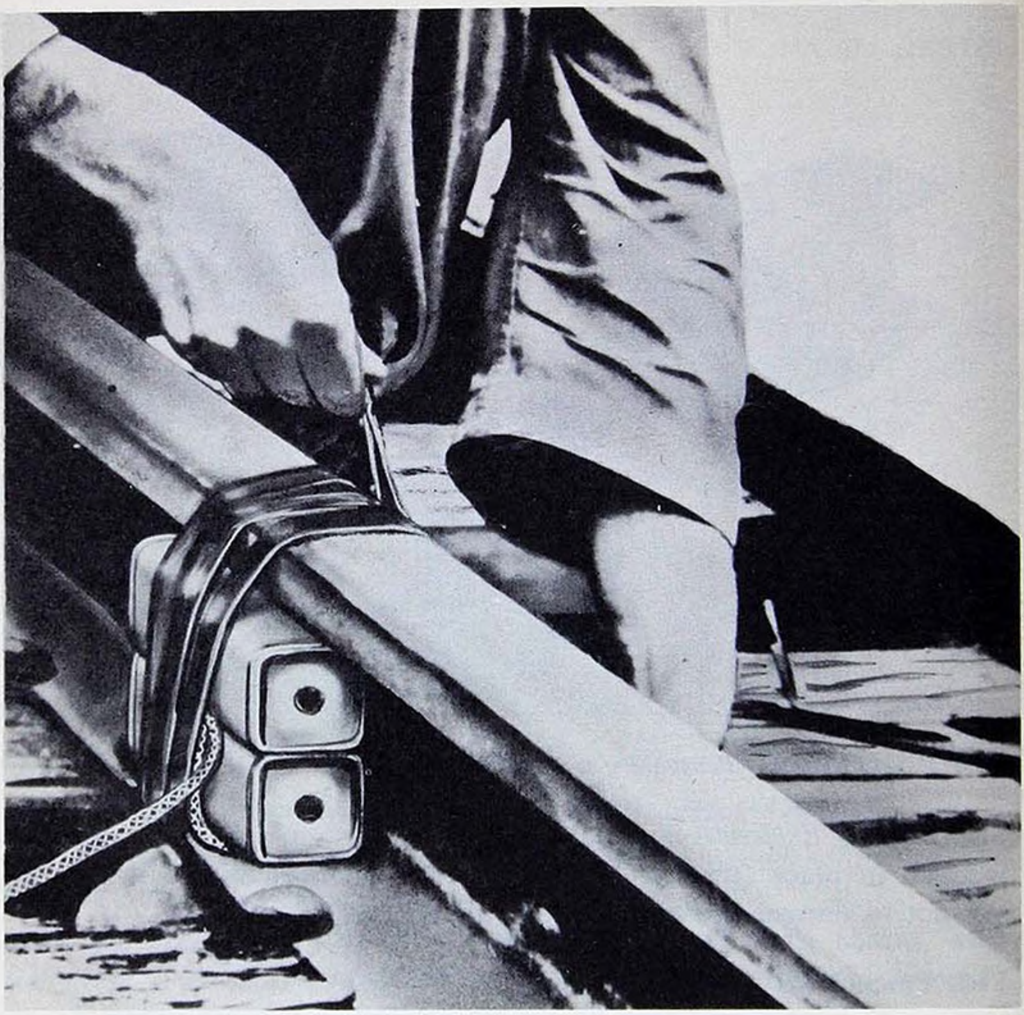


Figure 77. Placement of charges to cut steel railroad rail.

employed when a complete cut is desired. Both formulas and explosive methods are explained.

118. Calculation of Charges

a. Formula for Untamped External Charges. In cutting trees, piles, posts, beams, or other timber members with an untamped external charge, the following formula applies to either round or rectangular members:

For Composition C4* $P=C$ (for $C=O$ to $C=5\frac{1}{4}$ feet) and

$$P=\frac{C^3}{30} \text{ (for } C=5\tfrac{1}{2} \text{ feet to } C=9\tfrac{1}{4} \text{ feet)},$$

where P=pounds of explosive and C=circumference of tree or timber in feet. When the circumference exceeds 9¼ feet (36 in. diameter trees), cutting with explosives is not reliable unless excessive amounts of explosives are used.

*When TNT is used, increase P by ⅓.

ILLUSTRATIVE PROBLEM: How much Composition C4 and TNT will be required to cut a tree with a circumference of 45 inches (3.75 ft.) using an untamped external charge?

For C4 $P=C$

$P=3.75$ lbs

use 1½ blocks of C4

For TNT $P=C+\frac{1}{3}$

$P=3.75+1.25=5$ pounds

How much composition C4 and TNT will be required to cut a tree with a circumference of 75 inches (6.25 ft.)?

For C4 $P=\frac{C^3}{30}$

$P=\frac{244}{30}=8.13$ lbs

use 3¼ blocks

For TNT $P=C+\frac{1}{3}$

$P=8.15+3=11$ pounds

b. Formula for Cutting Trees to Create an Obstacle. The following formula applies when cutting trees to create an obstacle with an untamped explosive charge where it is desired to leave the tree attached to the stump:

For Composition C4 $P=\frac{D^2}{50}$

Where P=pounds of Composition C4 required, and
D=diameter of the timber in inches

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

Where P=pounds of TNT required, and
D=diameter of the timber in inches

Note. For timber having diameters larger than 28 inches, increase P by ¼.

ILLUSTRATIVE PROBLEM: How much Composition C4 or TNT will be required to cut a tree with a diameter of 15 inches, using an untamped external charge?

For C4 $P=\frac{D^2}{50}$

$P=\frac{225}{50}=4.5$ pounds

use 2 blocks of C4

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

$P=\frac{225}{40}=5.62$ pounds

use 6 pounds

c. Formula for Tamped Internal Charges. Tamped internal charges can be calculated with the following formula:

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

Where P=pounds of explosive required, and

D=diameter or least cross-sectional dimension in inches.

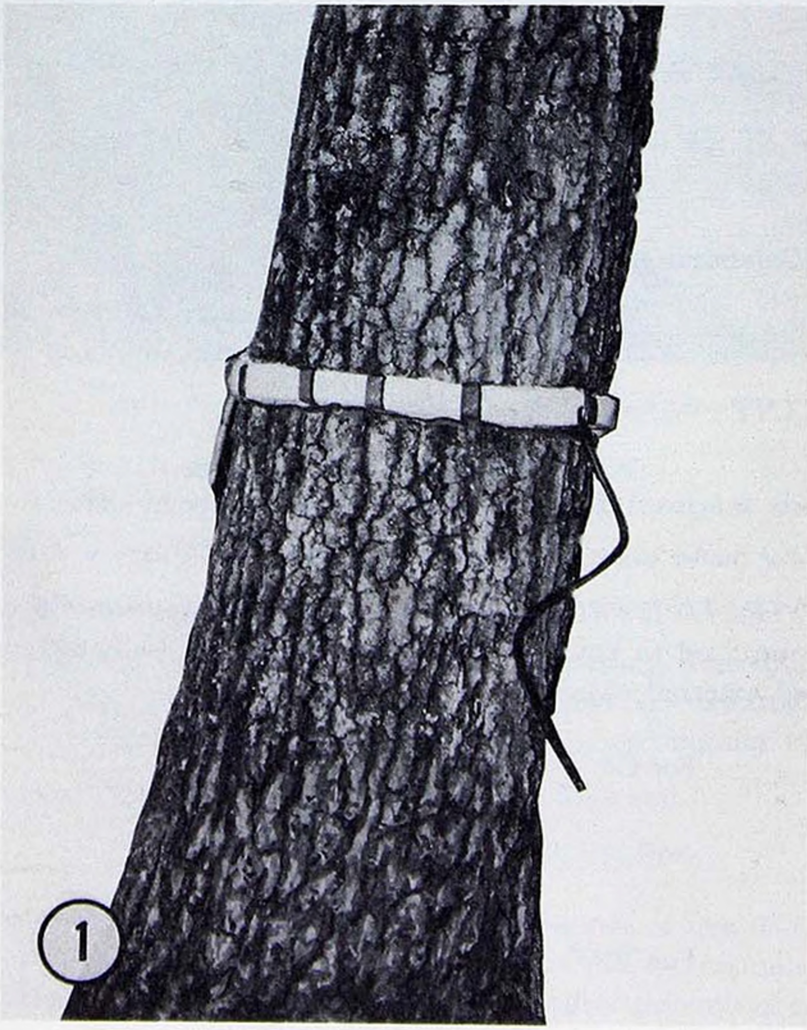
ILLUSTRATIVE PROBLEM: How much explosive will be required to cut a 15 inch diameter tree, using tamped internal charge?

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

$$P=15\times\frac{15}{250}=\frac{225}{250}=0.90$$

119. Placement of Charges

a. External Charges. External charges are placed as close as possible to the surface of the timber to be cut, regardless of the kind of cut desired. To completely sever the timber and obtain a clean cut, the

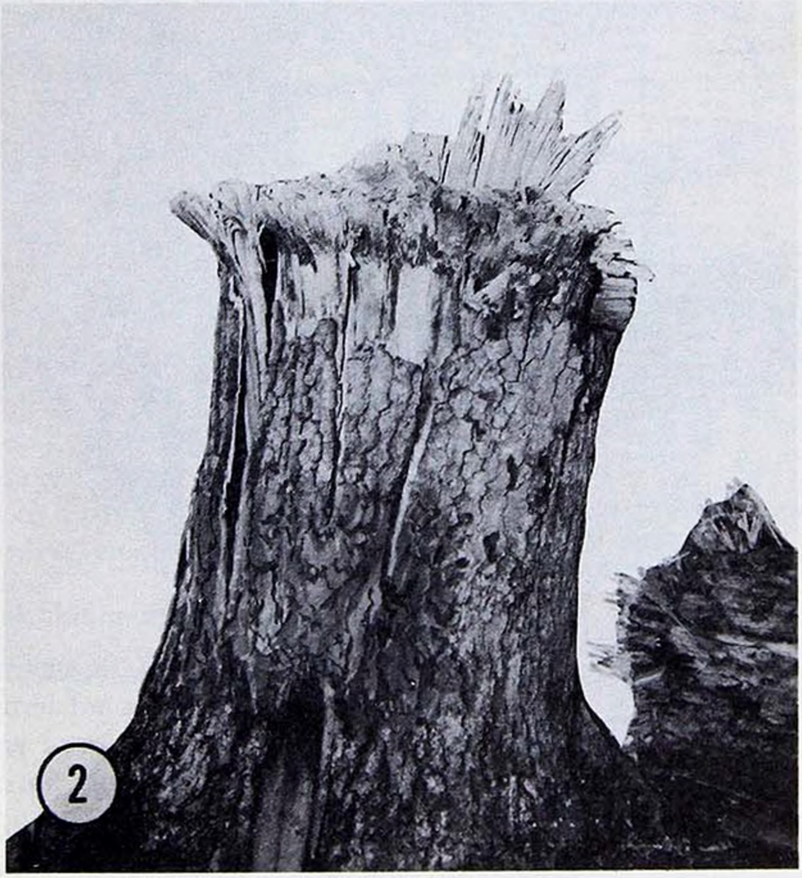


1 Composition C4 charge completely encircling tree.

Figure 78. External charges to cut timber.

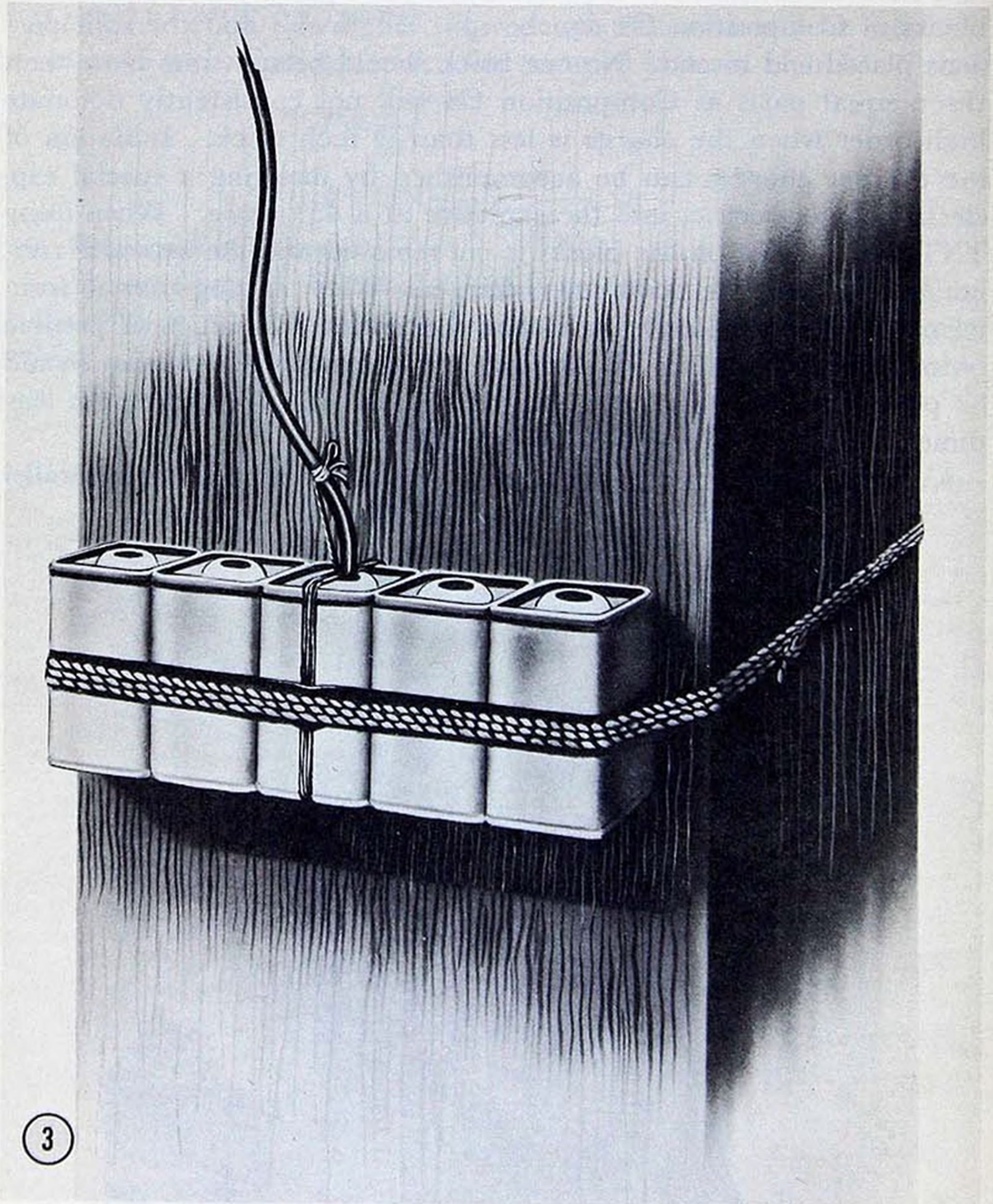
explosive must completely encircle the target (1 and 2, fig. 78). When using Composition C4 the charge can be first wrapped in strips of canvas or similar material and twisted tightly around the tree. The charges may be made up by removing the plastic cover from blocks of Composition C4 and placing the explosive end to end to form a ring around the tree. If lesser amounts of explosive are required the blocks of Composition C4 can be split lengthwise and the split portions placed end to end. No one block should be split into more than three equal parts as Composition C4 will not consistently detonate high order when the charge is less than ½ inch thick. Initiation of the thinner charges can be accomplished by inserting a special cap, electric or nonelectric, into the explosive at a 45° angle. When using TNT the covering on the blocks is not removed and the explosive cannot be split to make up thinner charges. When cutting trees to form an obstacle, the explosive should be concentrated as much as possible on one side of the tree. If the tree is not round the explosive should be placed on the widest face so that the cut will be through the least dimension (3, fig. 78).

b. Internal Charges. Internal charges are placed in boreholes parallel



2 Tree completely severed from stump

Figure 78—Continued.



3 Cutting timber to form an obstacle

Figure 78—Continued.

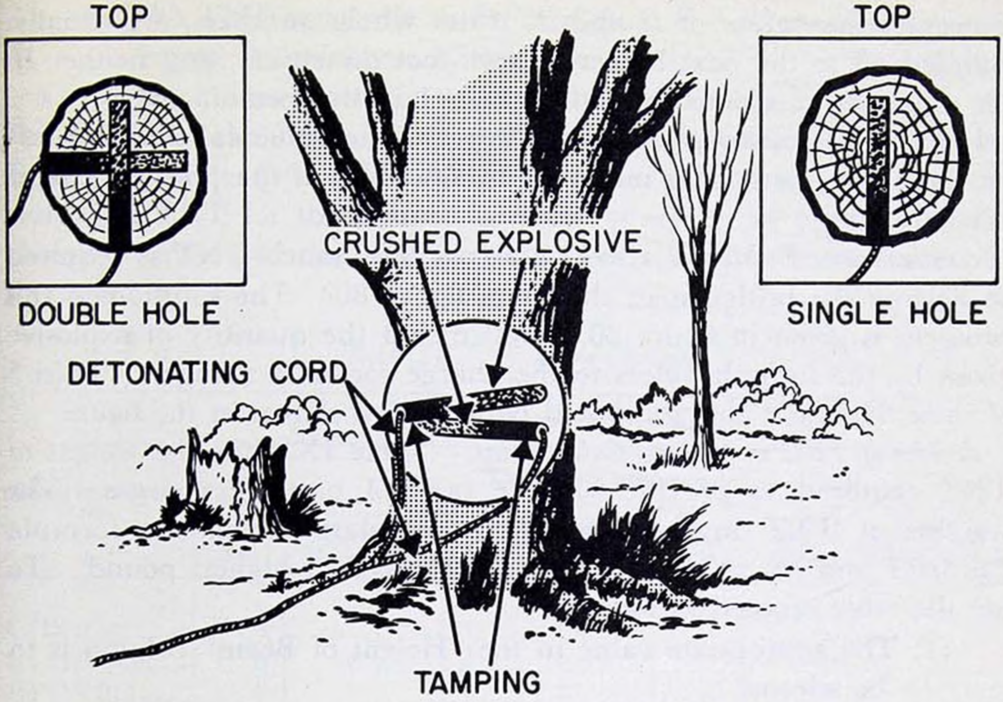


Figure 79. Internal charges to cut round timber.

with the greatest dimension of timber cross section. They are tightly tamped with moist earth or clay. If the charge is too large for 1 borehole, 2 holes are bored close together. For round timber the 2 holes are bored at approximately right angles to each other (fig. 79). Both boreholes are primed and both are fired simultaneously.

Section IV. PRESSURE CHARGES

120. General

Pressure charges are effective against simple span, reinforced concrete, T-beam bridges. The effect of the explosion is to partially breach and overload the span. This causes the bridge to break in midspan and pull free from the abutments or piers. The use of pressure charges, as calculated by the formula in paragraph 121, against continuous span reinforced concrete T-beam bridges is virtually a waste of explosives, since satisfactory demolition will not result.

121. Calculation of Pressure Charges

a. Formula for Tamped Pressure Charges. The amount of TNT which is required for a tamped pressure charge can be calculated with the following formula. When using explosive other than TNT, the calculated value must be adjusted as described in paragraph 110*b*.

$$P = 3H^2T$$

where 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, are usually rounded off to the next higher quarter-foot dimension, and neither *H* nor *T* is ever considered to be less than 1 in the formula.

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.

c. Illustrative Problem: Pressure Charges. How much TNT is required to destroy the bridge span shown in figure 80? The solution to this problem is given in figure 80. Notice that the quantity of explosive given by the formula refers to the charge for each stringer. Thus 5 of these 34-pound charges should be placed as shown in the figure.

d. Use of Table in Making Calculations. Table IX gives the weight 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 rounded off to the next highest pound. To use the table proceed as follows:

(1) The appropriate value in the "Height of Beam" column is to be selected.

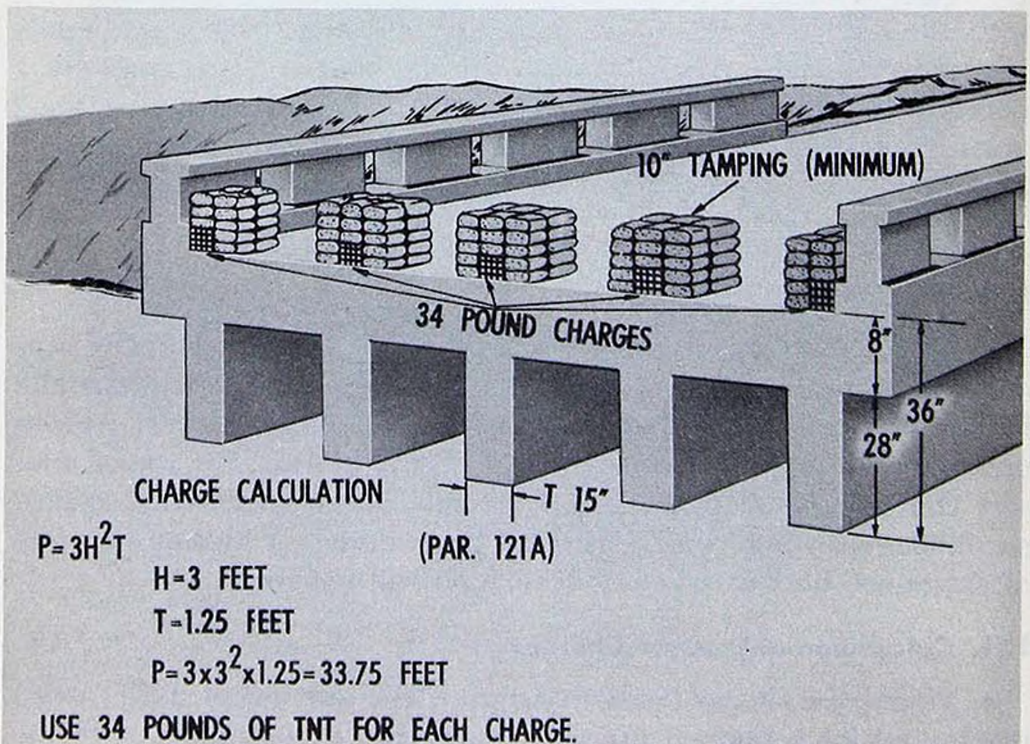


Figure 80. Calculation and placement of pressure charges.

(2) The TNT weight is to be read from the column corresponding to the thickness of the base.

e. Example. For example, to solve the problem given in figure 80, the height of the beam is 36 inches and the thickness is 15 inches. From the table (36-inch height and 15-inch column) the necessary weight of TNT for the tamped pressure charge is 34 pounds. If the charge is untamped then the weight values given in the table must be increased by ⅓.

Table IX. Pressure Charges

Height of beam in feet	Pounds of explosive for each beam (tamped charges)* — 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 amounts by ⅓ when charges are untamped.

122. Placement of Charges

An appropriate explosive of the correct size is placed over the center line of each stringer (fig. 80). All charges rest on the roadway and are alined midway between the ends of the span. Where a curb or siderail prevents placing the charge directly above the outside stringer, the charge is placed against the curb or siderail. This placement does not require an increase in the explosive charge. Pressure charges should be tamped whenever possible. A minimum of 10 inches of tamping is required if the tamping is to be effective. If, because of lack of time or materials, tamping becomes impracticable, the charge must be increased in accordance with paragraph 121*b*. All charges should be so primed that they can be fired simultaneously.

Figure 81. Effect of pressure charges on a simple span concrete T-beam bridge.

123. Effects of Explosion

Pressure charges usually blow out the concrete completely across the roadway over a length equal to about twice the height of the stringer. Thus, no additional charges are required to demolish the roadway. The simple span bridge is broken at the point of the explosion and either broken or dislodged at its supports (fig. 81). It is easy to understand, therefore, why a continuous span bridge is not satisfactorily demolished by the application of pressure charges, as the ends are not free to break or pull away from the supports. The effective demolition which pressure charges have accomplished on the simple span

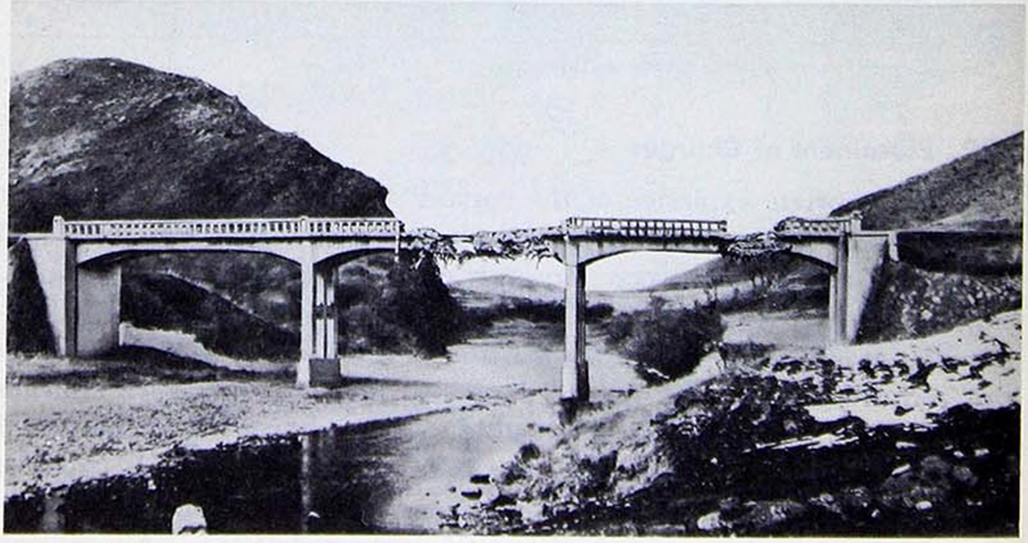


Figure 82. Poor results obtained when pressure charges are used on a continuous span concrete T-beam bridge.

shown in figure 81 should be noticed. The ineffectiveness of the demolition accomplished by similar charges should be compared with the results on the continuous span shown in figure 82.

Section V. BREACHING CHARGES

124. General

The most important use of breaching charges is in the destruction of bridge piers, bridge abutments, and field fortifications of a permanent type. They may also be used to breach walls and to blow holes in concrete slabs and roadways.

125. Calculation of Breaching Charges

a. Formula. The size of a TNT charge to breach concrete, masonry, rock, or similar material is calculated by the following formula. Suitable adjustment to the *P*-value which this formula gives will indicate the size charge for any other explosive.

$$P=R^3KC$$

where P=pounds of TNT required

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

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

C=a tamping factor, given in figure 83, which depends on the location and tamping of the charge (*d* below).

Note. For breaching walls 1 foot in thickness and under, increase the total calculated charge by 50 percent. Add 10 percent for charges under 50 lbs.

Table X. Values of Material Factor K for Use in 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 reinforcing steel).	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

b. Breaching Radius R. The breaching radius *R* is the distance, in feet, from an explosive, within which all material is displaced or destroyed. The breaching radius, for external charges, may be taken

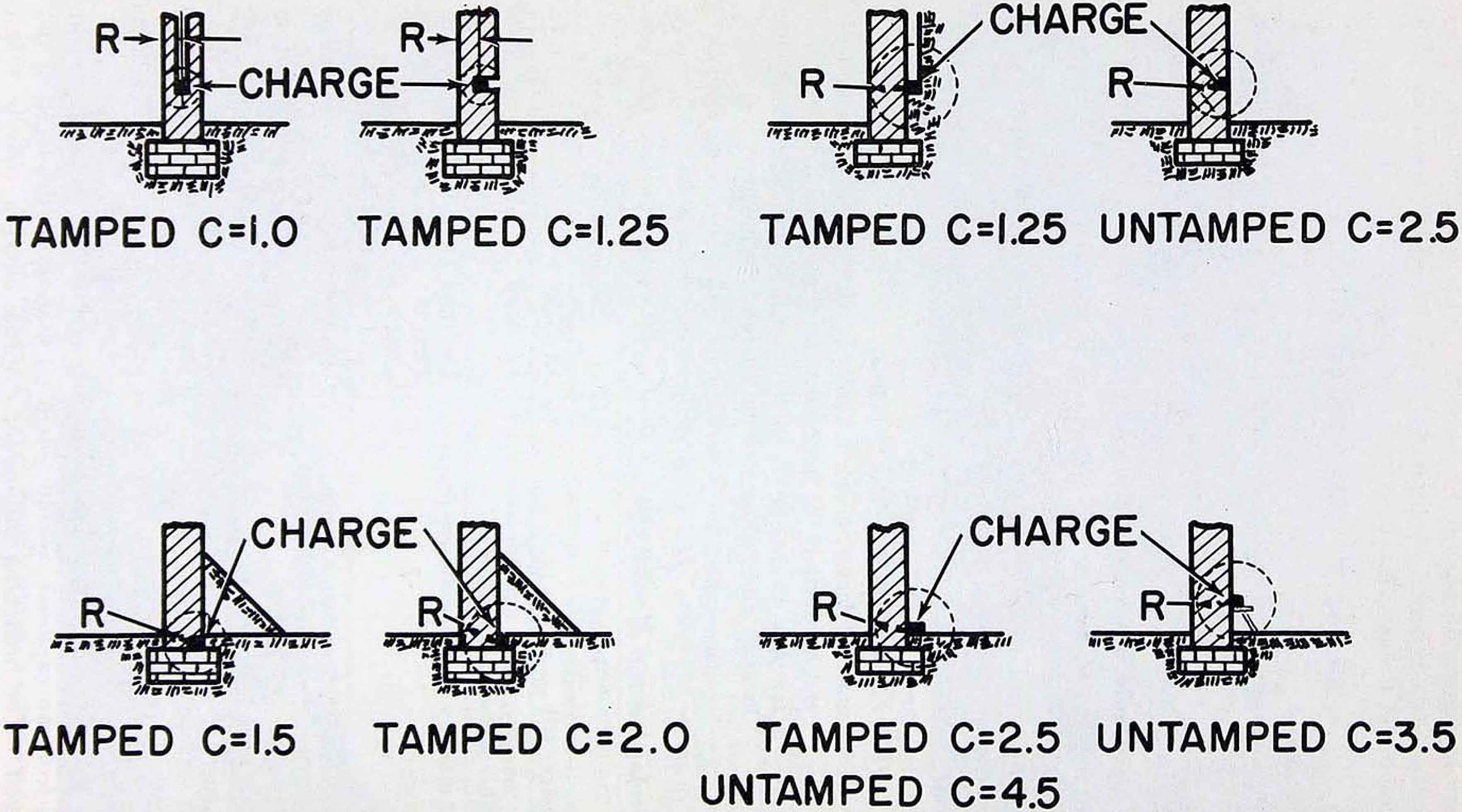


Figure 83. Values of C (tamping factor) for breaching charges.

as the thickness of the mass to be breached. The breaching radius for internal charges may be taken as 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 drill hole to the outside of the mass. For example, if a 4-foot wall is to be breached by an internal charge placed 1 foot into the mass, the breaching radius is taken as 3 feet. If it is to be breached by a centered internal charge, the breaching radius is taken as 2 feet. The breaching radius is 4 feet if an external charge is used.

c. Material Factor K. K is a factor which reflects the strength and hardness of the material to breach. Table X 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 83 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 83, a charge tamped with a solid material such as sand or earth is not considered fully tamped unless covered to a depth equal to the breaching radius.

126. Placement and Number of Charges

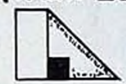
a. General. In the hasty demolition of piers and walls, the possible positions of the explosive charges are rather limited. Unless a demolition chamber is available, the charge (or charges) may be placed against one face of the target either at ground level, somewhat above ground level, or beneath the surface of the ground. A charge placed above ground level is more effective than one placed directly on the ground. When several charges are required to destroy a pier, slab, or wall, they are distributed equally at least ⅓ the total height from the base of the object to be demolished. In this manner the best use can be obtained from the shock waves of the blast. All charges are to be thoroughly tamped with damp earth and wet sandbags if time permits. For those piers, slabs, or walls that are partially submerged in water, charges should be placed below the water line. If underwater demolition is essential the tamping factor for the placement of charges in air is used.

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

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

When N = number of charges
W = width of pier, slab, or wall, in feet, and
R = breaching radius in feet (par. 125*b*)

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.

When the calculated value of N contains a fraction less than ½, the fraction is disregarded, but when the calculated value of N contains a fraction of ½ or more, the value is rounded off to the next highest whole number. An exception exists to this general rule in the case of calculated N-values between 1 and 2. In this instance a fraction less than ¼ is disregarded, but a fraction of ¼ or more is rounded off to the next higher whole number, 2.

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

d. Example Problem. Using the table, how much TNT is required to breach a reinforced concrete wall 7 feet in thickness with a tamped charge placed a distance R above the ground? From the table (7-foot thickness and tamped charges places a distance R above the ground columns) the necessary weight of TNT is 185 pounds.

127. Effects of Explosion

High-explosive breaching charges, detonated in contact with concrete, masonry, or rock, deliver a shock so intense that the material is broken or shattered. Any reinforcing in concrete is not cut by this charge.

Section VI. CRATERING, DITCHING, AND LAND CLEARING

128. Road Craters

Road craters, to be effective obstacles, must be too wide to be spanned by track-laying vehicles and too deep and too steep-sided for vehicles to pass through them. Road craters must be large enough to tie into either natural or man-made obstacles at each end. Antitank and antipersonnel mines placed as described in FM 20–32 increase the effectiveness of craters by hampering repair operations.

129. Breaching Hard-Surface Pavements

Hard-surfaced pavement is breached so that holes can be dug for cratering charges. This is done effectively by placing tamped charges on the pavement surface. A 1-pound charge of explosive is used for each 2 inches of pavement thickness, with tamping twice as thick as the pavement. Pavement may be breached by charges placed in boreholes drilled or blasted through the pavement. 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 on only 1 side of the joint.

130. Deliberate Road Crater

The deliberate road crater can be made in all materials except loose sand, regardless of the type of road surface. The method shown in

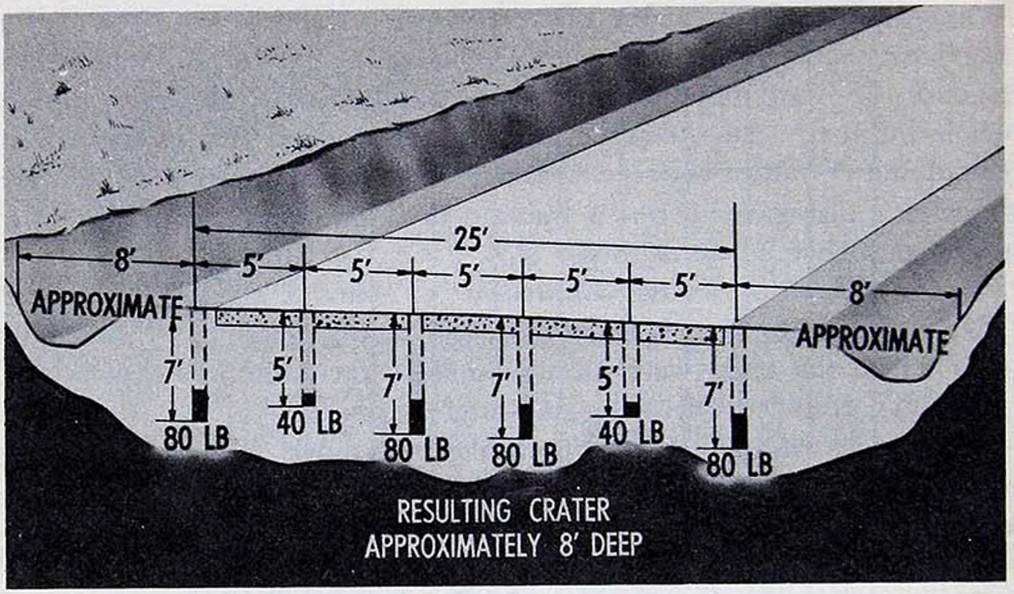


Figure 84. Placement of charges for a deliberate road crater.

figure 84 produces a clean V-shaped crater about 8 feet deep and 25 feet wide extending about 8 feet beyond each end charge. Any explosive gives good results but the 40-pound ammonium nitrate cratering charge is less expensive and easier to place than other explosives. It is especially designed for this purpose. The method of placing charges is as follows:

a. Holes are to be bored 5 feet apart, center-to-center, in line across the roadway. The end holes are to be 7 feet deep and the other alternately 5 feet and 7 feet deep.

b. Eighty pounds of explosive are to be placed in the 7-foot hole and 40 pounds of explosive in the 5-foot holes. The two 5-foot holes are not to fall next to each other. If this does happen, one of them is to be made a 7-foot hole. The two adjacent 7-foot holes which result can be placed anywhere along the line of holes, although it is preferable to have them near the middle.

c. All charges are to be primed and connected to fire simultaneously. A dual firing system should be used.

d. All holes are to be refilled and tamped tightly.

131. Hasty Road Crater

Construction of a hasty road crater (fig. 85) takes less time and less explosive than does the construction of a deliberate road crater, but the depth and shape of the hasty crater may be less desirable. The hasty method is especially adaptable for blowing craters in hard soil when only hand tools are available for digging boreholes. The method described below produces a crater about 1½ times deeper and five times wider than the depth of the boreholes, and about 16 feet longer than the line of boreholes. The sides have a slope of 30° to 60°, depending upon the soil. Craters created by boreholes less than 4 feet

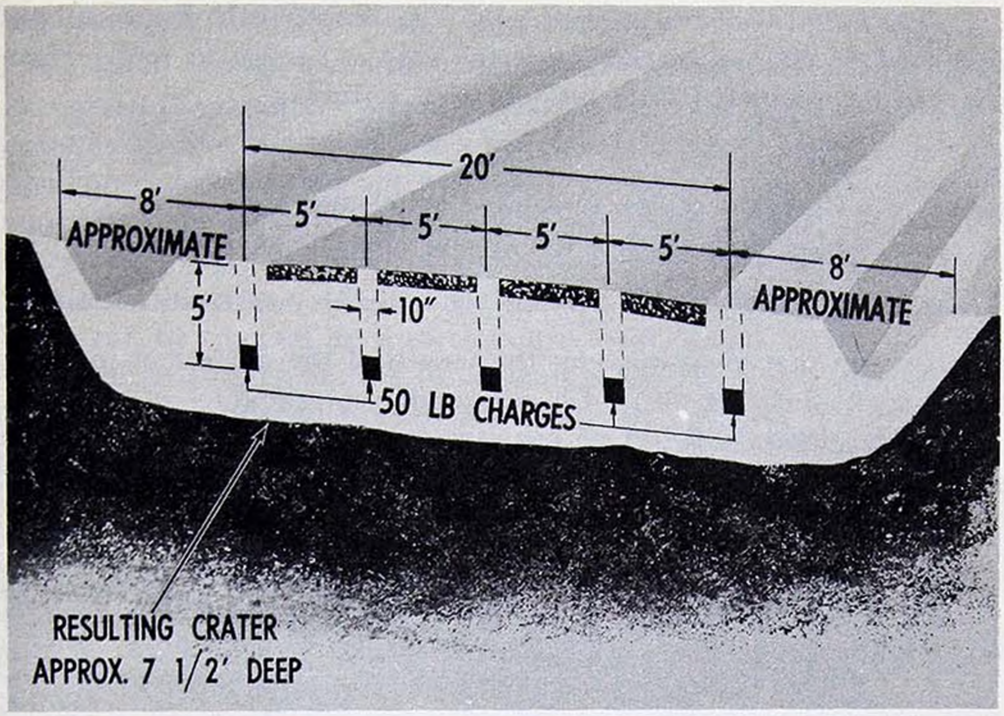


Figure 85. Placement of charges for a hasty road crater.

deep and loaded with a 40-pound charge in each hole are ineffective against tanks. The method to be used is as follows:

a. Boreholes are to be dug to the same depth. This depth may vary from 2½ feet to 5 feet, depending upon the size of the crater desired. The holes are to be spaced 5 feet apart, center-to-center, across the road.

b. The boreholes are loaded with 10 pounds of explosive per foot of depth.

c. Charges are to be primed as for deliberate cratering.

d. The holes are refilled and tamped.

132. Road Cratering at Culverts

a. General. A road crater can be blown and a culvert not more than 15 feet deep can be destroyed with the same charges. Destroying culverts deeper than 15 feet requires an excessive amount of labor and an excessive quantity of explosive. The explosive charges should be connected for simultaneous firing. The boreholes should be thoroughly tamped with sandbags. The calculation and placement of the charges are given below for culverts with different depth fills above them.

b. Shallow Fills. Culverts covered with less than a 5-foot fill may be destroyed by explosive charges placed as for the hasty road cratering method (par. 131*a*). Concentrated charges, equal to 10 pounds per foot of depth, are placed in boreholes in the fill above and alongside the culvert. They are located at 5-foot intervals along its length.

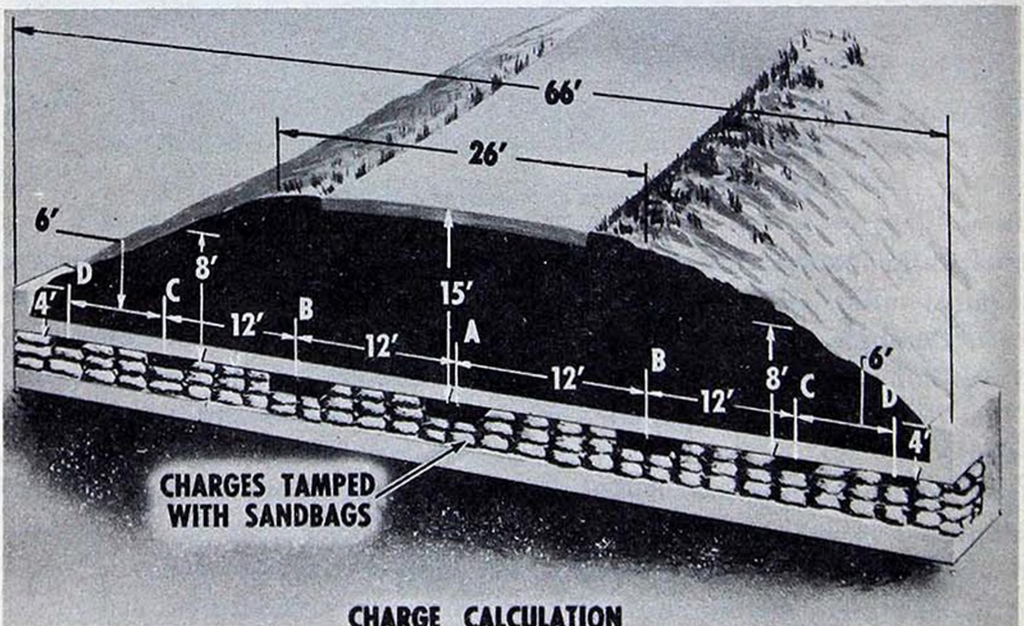
c. Deep Fills. Culverts covered with from 5 feet to 15 feet of fill are destroyed by charges placed inside the culvert against its roof. These charges are calculated from the following formula:

$$P = 2D^2$$

where P = Pounds of explosive required per charge, and
D = Maximum depth in feet at which the charge is placed

Note. For fractions of a foot of depth, the next higher foot is used in the calculation.

Charges are spaced throughout the length of the culvert at intervals equal to ⅘ of D (fig. 86). Charges under the shoulder of the road, where the depth is 5 feet or less, are calculated on the basis of 10 pounds of explosive per foot of depth of the shoulder. These road shoulder charges are spaced 5 feet apart.



CHARGE CALCULATION

FORMULA: $P = 2D^2$

CHARGES A AND B

$P = 2D^2 = 2 \times 15^2 = 450$ LB

DISTANCES A-B AND B-C

DISTANCE $= 4/5D = 4/5 \times 15 = 12$ FT

CHARGES C

$P = 2D^2 = 2 \times (8)^2 = 128$ LB

DISTANCES C-D

DISTANCE $= 4/5D = 4/5 \times 8 = 6\ 2/5$ FT

CHARGES D

$P = 10D = 10 \times 4 = 40$ LB

TAMP CHARGES THOROUGHLY WITH SANDBAGS

Figure 86. Placement of cratering charges in a culvert.

133. Antitank Ditch Cratering

a. General. In open country antitank ditches may be constructed to strengthen prepared defensive positions. They are costly to construct in terms of time and effort and consequently much is gained if the excavation can be carried out by cratering charges. To be effective an antitank ditch must be wide enough and deep enough to trap the enemy tank (fig. 87). Such ditches can be improved by placing a log hurdle on the enemy side and the spoil on the friendly side. Medium tanks can be stopped by a ditch 6 feet deep and 12 feet wide. For heavy tanks a ditch should be at least 8 feet deep and 25 feet wide at the top. Antitank ditches are improved by using hand tools or equipment to make the face of the ditch nearly vertical on the friendly side.

b. Deliberate Cratering Methods. The deliberate cratering method as outlined in paragraph 130 is well suited for the construction of heavy tank antitank ditches in most types of soil. The use of alternate 5-foot and 7-foot holes spaced at 5-foot intervals and with 40-pound charges in the 5-foot holes and 80-pound charges in the 7-foot holes gives a V-shaped crater approximately 8 feet deep and 25 feet wide.

c. Hasty Cratering Method. Ditches for medium tanks can be constructed by placing 40 pounds of cratering explosive in 4-foot holes spaced 5 feet apart. The resulting ditch will be approximately 6 feet deep and 20 feet wide. A heavy tank antitank ditch can be constructed by placing 50-pounds of cratering explosives in 5-foot holes

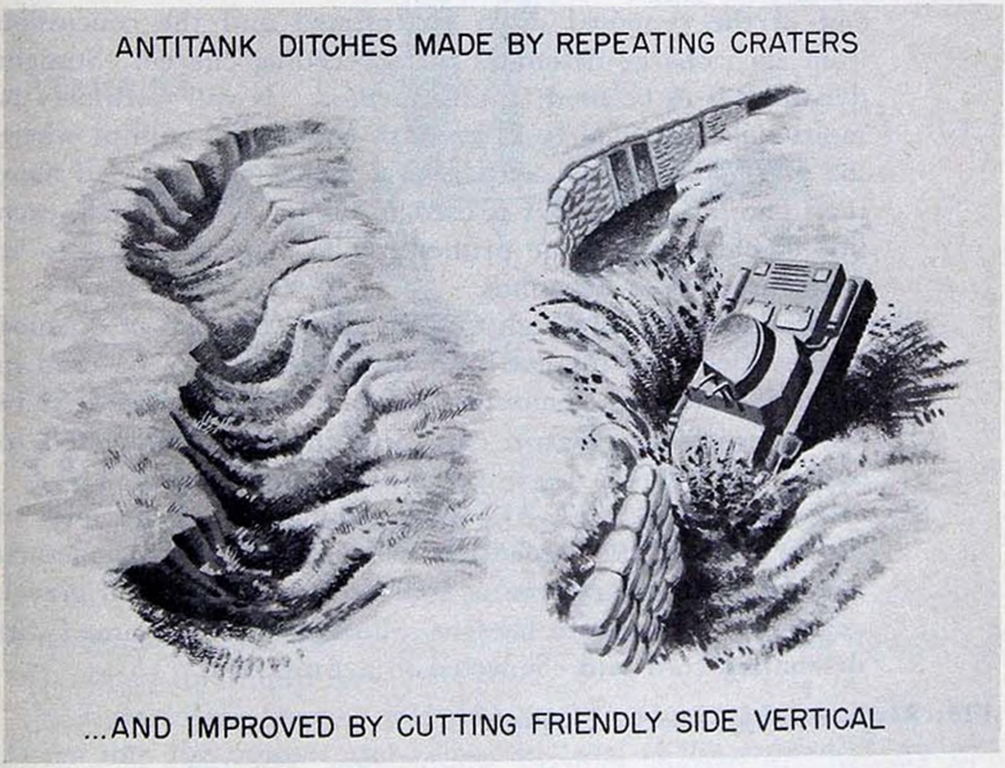


Figure 87. Antitank ditch constructed with cratering charges.

and spacing the holes at 5-foot intervals. The resulting ditch will be about 8 feet deep and 25 feet in width.

134. Blasting Ditches

a. General. In combat areas it may be necessary to construct ditches to drain areas which have been flooded by the enemy. Ditches can be used as initial excavations for the preparation of entrenchments. Rough open ditches 2½ to 12 feet deep and 4 to 40 feet wide can be blasted in most types of soils. Detailed instructions for blasting ditches can be found in FM 5–34. A brief outline of the procedure is given below.

b. Test Shots. Before attempting the actual ditching, test shots are to be run to determine the proper depth, spacing, and weight of charges needed to obtain desired results. Test shots are begun with holes 2 feet deep and 18 inches apart for small ditches and increased in charges and depth as required.

c. Alinement and Grade. Ditch centerlines are to be marked by chalk or transit line and holes drilled along it. When a transit is used the grade of the ditch can be accurately controlled by checking the hole depth every 5 to 10 holes and at each change in grade. In soft ground, the holes can be drilled with a miner's drill or earth auger. Holes are to be loaded and tamped immediately to prevent cave-ins and insure that the charges are at proper depth.

d. Detonating Methods.

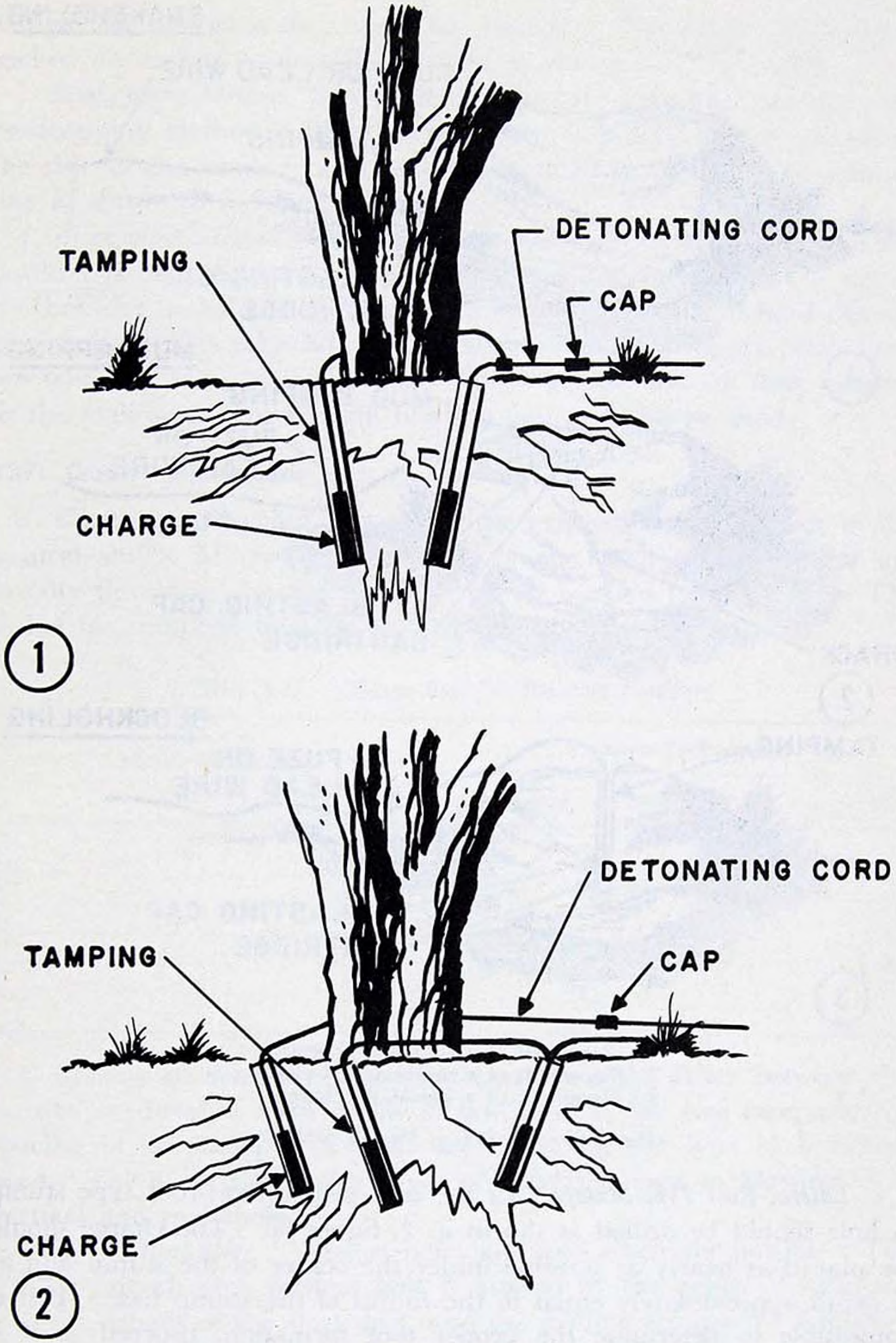
(1) *Propagation methods.* In this method, the hole, or holes, at one end of the proposed ditch are primed and the concussion from each charge detonates the succeeding charge. Straight dynamite is to be used for this method. It will work only in moist soils, particularly in swamps containing stumps where the ground is covered with several inches of water. If more than one line of charges is used to obtain a wide ditch, each line of charges is to be primed. The primed hole is to be overcharged 1 or 2 pounds.

(2) *Electrical method.* Any high explosive may be used in ditching by the electrical method and the method may be used in any soil regardless of moisture content. Each charge is to be primed with an electric cap, and the caps connected in series. All charges are to be blown simultaneously.

(3) *Detonating cord method.* Any high explosive may be used in ditching with the detonating cord method. This method may be used in any type of soil, excluding sand and gravel, regardless of moisture content. Each charge is primed with detonating cord and connected to a trunk line.

135. Removal of Stumps by Blasting

a. General. In certain military construction operations it may be necessary to remove stumps in addition to removing trees. Stumps are

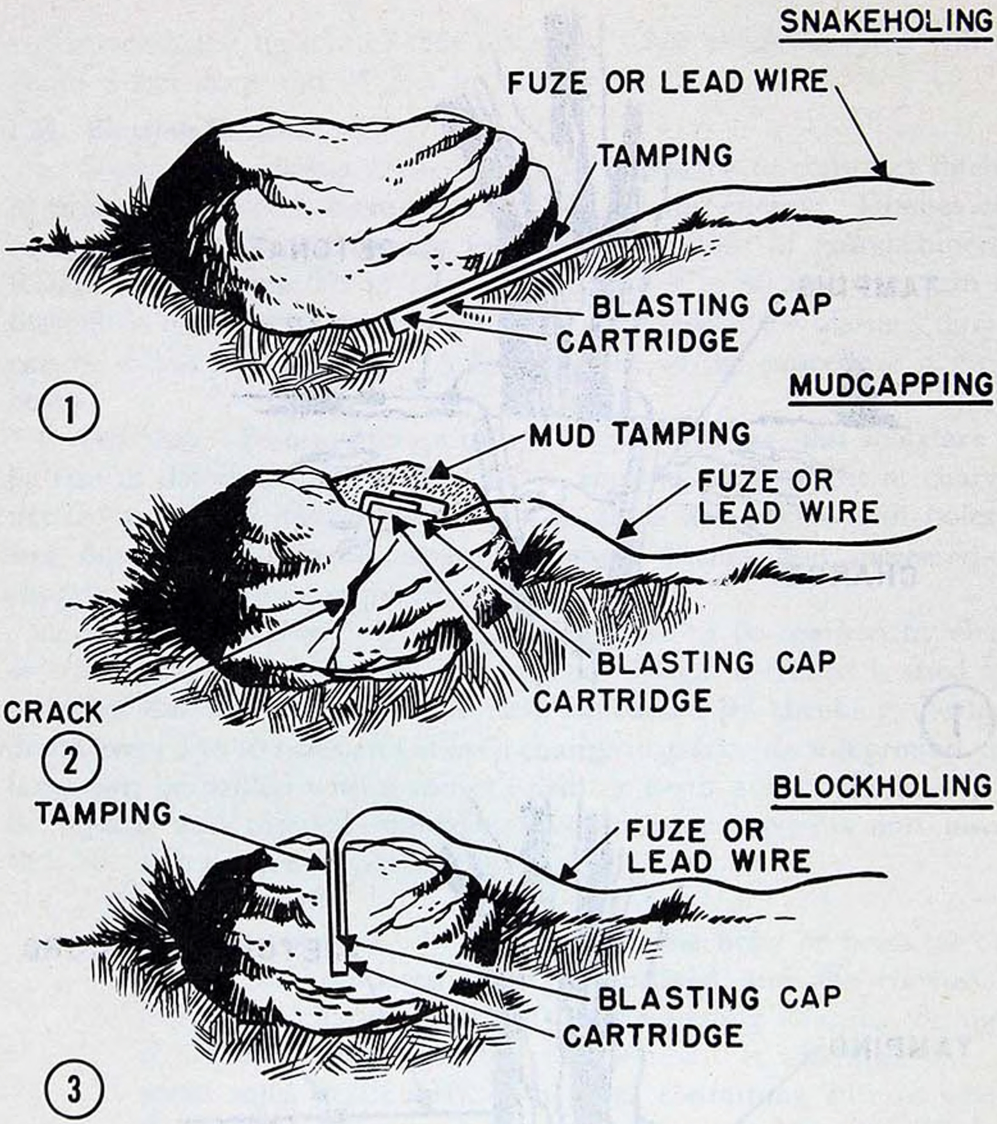


1 Placement of charge for taprooted type stumps
2 Placement of charge for lateral-rooted type stumps

Figure 88. Stump blasting.

of two types, either tap or lateral rooted. A low velocity dynamite is best suited for stump removal.

b. Taproot Type Stumps. For a taproot type stump a hole must be bored into the taproot and below the level of the ground (1, fig. 88). For best results the charges should be tamped.



1 Placement of a snakehole charge
2 Placement of a mud-capped charge
3 Placement of a blockhole charge

Figure 89. Methods of blasting boulders.

c. Lateral-Root Type Stumps. In the case of a lateral-root type stump a hole should be drilled as shown in 2, figure 88. The charge should be placed as nearly as possible under the center of the stump and at a depth approximately equal to the radius of the stump base. If it is impossible to determine the proper root formation, proceed as if it were of the lateral root type. See FM 5–34 for further information.

136. Removal of Boulders by Blasting

a. General. In the construction of roads and airfields or in other military construction operation., it is often necessary to remove boulders. The most practical methods of removing boulders are by snakeholing, mudcapping, and blockholing.

b. Snakeholing Method. In the snakeholing 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 1, figure 89.

c. Mudcapping Method. For surface or slightly imbedded boulders, the mudcapping method is ideal. The charge is placed on top or against the side of the boulder and covered with 10 or 12 inches of mud or clay as shown in 2, figure 89.

d. Blockholing Method. The blockhole method can also be used if the boulder is on the surface or slightly imbedded in earth. On top of the boulder, a hole is drilled deep and wide enough to hold the explosive required in table XII. The contents of the cartridges is poured into the hole and tamped (3 fig. 89). The cap and fuze are then inserted in the explosive. An electric blasting cap can also be used.

137. Quarry Operations

a. General. Quarrying pertains to the extraction of hard rock in the natural state. Military quarries are of the open face type and are usually developed by the multiple bench method (fig. 90). See TM 5–254 for complete detailed information on quarry operations.

Table XII. Charge Size for Blasting Boulders

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

b. Spacing of Boreholes. A definite relationship exists between the burden or distance from a row of boreholes to the free face, and the spacing of boreholes in a row, depending on the type of boreholes used. There are two major types of boreholes used in blasting rock, vertical and snakehole.

(1) *Vertical holes.* Vertical holes are used whenever possible. The depth of a vertical hole is limited by the depth of rock, the length of the steel drill, and the drilling equipment available. The spacing of the boreholes is equal to or a little more than the burden. If several rows are drilled the burden of the holes in the rear rows is 10 percent less than that of the front row for better breakage (fig. 91).

(2) *Snakeholes.* Snakeholes are drilled at the base of the quarry face and started at a point from 2 to 4 feet above the floor. They are sloped downward so that the end of the hole is at the level of the quarry floor. All snakeholes must be sloped

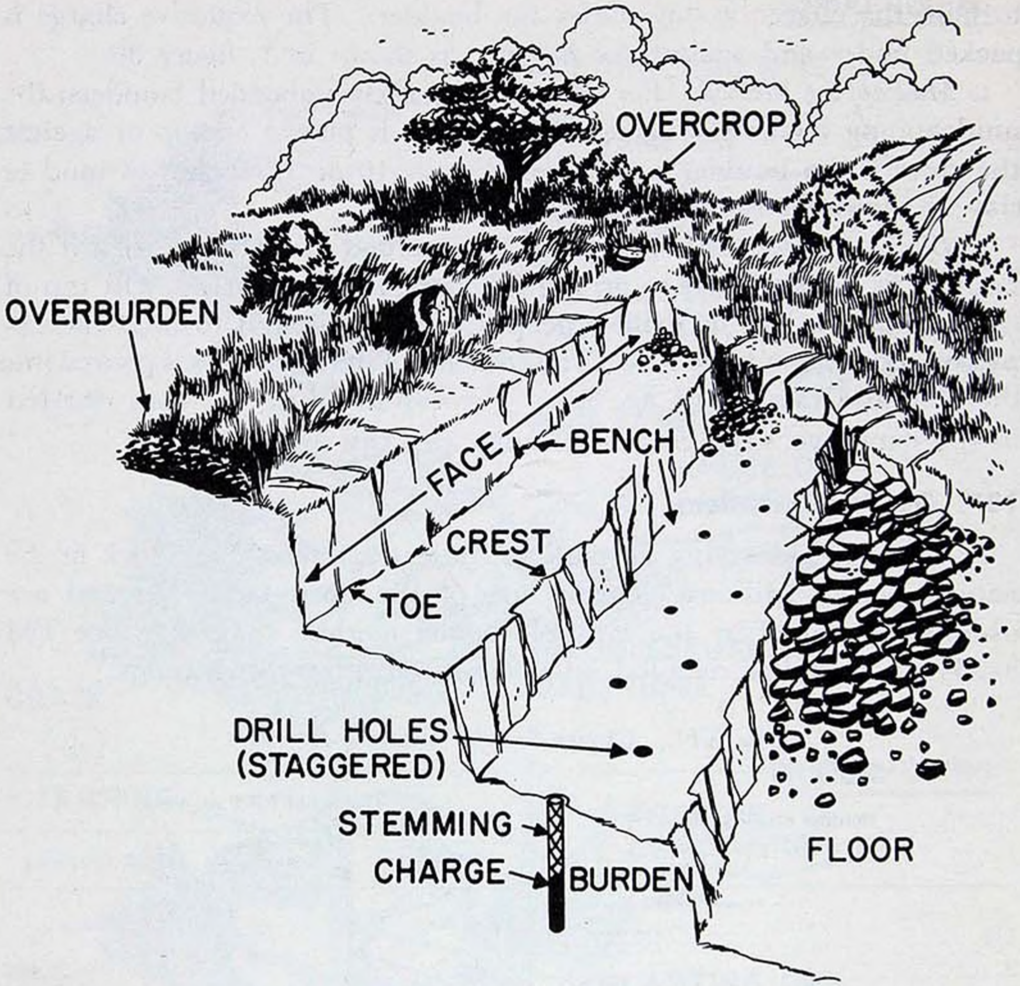


Figure 90. Multiple bench method.

at the same angle and stop at the same level. Snakeholes will have a burden equal to ½ the height of the face with spacing generally between 8 to 10 feet. When necessary, they may be sprung to contain the entire charge.

c. Amount of Explosives. Normally one pound of explosive will shatter from 1 to 3 tons of hard rock and from 3 to 5 tons of soft rock. An approximate amount of explosives to use per foot of borehole is given in table XIII.

d. Explosives. Dynamite is the most commonly used explosive in quarry operations. Commercial dynamite such as 40 and 60 percent gelatin dynamite can be detonated by a Number 6 or larger blasting cap. Military dynamite can be exploded by the special blasting cap, either electric or nonelectric.

e. Priming.

(1) *Electric blasting caps.* To fire charges with an instantaneous electric blasting cap, the primed cartridge is placed next to the bottom charge in the borehole or in the center of long charges in certain types of dynamite. After the primer has

Table XIII. Amount of Explosive per Foot of Borehole

Average diameter of hole in inches	Explosive per foot in pounds*	Average diameter of hole in inches	Explosive per foot in pounds*
1½	0. 65	5	7. 40
1¾	0. 90	5½	8. 30
2	1. 20	5⅝	9. 35
2½	1. 85	6	10. 60
3	2. 70	6½	12. 50
3½	3. 65	7	14. 50
4	4. 75	8	18. 90
4½	5. 95		

Note. ⅔ depth of hole explosive, ⅓ stemming.

*Estimates based on 40 percent dynamite in traprock.

been loaded, at least one cartridge is placed between it and the stemming. Cartridges are not to be slit or tamped. When using delay electric blasting caps, the primer is to be placed at the bottom of the borehole with the detonator pointing toward the charge.

(2) *Detonating cord.* When detonating cord is used, the primed cartridge is placed in the bottom of the borehole with the detonating cord running the entire length of the charge. The charge is to be tamped carefully to prevent damaging the detonating cord. The detonating cord can be detonated by either an electric or nonelectric blasting cap.

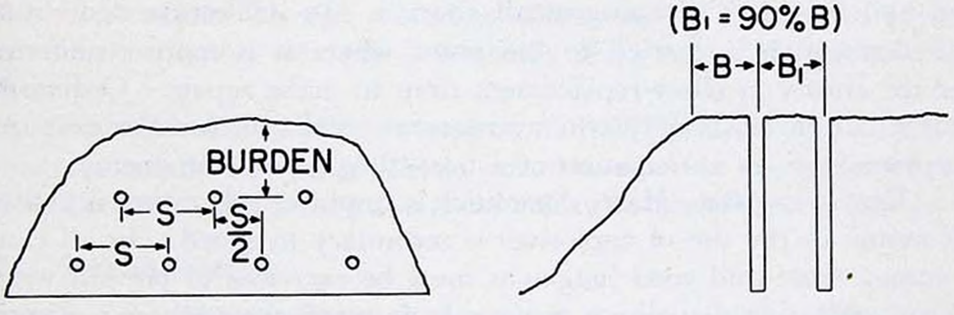


Figure 91. Arranging parallel rows of vertical holes.

f. Testing and Firing. Each electric blasting cap is to be tested with a galvanometer before it is placed in a circuit. Boreholes should be checked to see that they are properly loaded, primed and connected to the circuit. The blaster must be certain that all is clear before connecting the lead wires to the blasting machine.

g. Secondary Blasting. Secondary blasting is employed when the primary blast fails to break rock small enough for shovel or crusher operations. Secondary blasting is accomplished principally by blockholing, mudcapping, and snakeholing (par. 136).

CHAPTER 7

CONSIDERATIONS AND METHODS FOR DEMOLITION PROJECTS

138. Purpose

The purpose of military demolitions is either to impede the enemy, deny him the use of selected facilities and equipment, or to facilitate the movement of friendly troops. This is accomplished by destroying or making bridges, airfields, roads, and important items of abandoned equipment unusable and by destroying or breaching enemy obstacles.

139. Methods

a. General. Demolition is usually accomplished by fire, water, mechanical means, artillery fire, aerial bombing, or hand-placed explosive charges. In general, demolition by hand-placed explosive charges is the most rapid, most certain, most effective, and most economical method.

b. Deliberate Demolition. Deliberate demolition is used when enemy interference during preparations is unlikely and there is sufficient time for thorough reconnaissance and careful preparation. Deliberate preparation permits economy of explosives, since time permits judicious placing and thorough tamping of all charges. In deliberate demolition, the destruction is carried to the point where it is more economical for the enemy to effect replacement than to make repair. Ordinarily, this situation exists only when structures in rear areas are prepared for demolition in anticipation of a breakthrough by the enemy.

c. Hasty Demolition. Hasty demolition is employed when time is limited. Economy in the use of explosives is secondary to speed. In all cases, common sense and good judgment must be exercised to prevent waste. When preparing demolition projects in forward areas where a surprise rail by hostile forces is possible, a priority should be placed on each charge. Each charge is primed as it is placed. Although this method is more time consuming, it will cause maximum damage to be done to the project for the time it is worked on, even though enemy interference might prevent completion of the job. On the other hand, if charges are all placed before priming, it is possible that enemy interference prior to the act of priming could cause stoppage of work without any damage to the project having been accomplished. The use of dual detonating cord lines to initiate buried charges and trunk lines, where appropriate with cap exposed to view, is recommended for hasty demolition.

d. 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 effective to destroy a large railroad bridge than to use the same amount of explosive to destroy railroad track.

e. Thickening Obstacles. Nuisance mining and the use of chemical contaminants are effective means of increasing the hindrance caused by demolition projects. The area to be mined should include the destroyed facility, the area where a replacement structure or remedial work would 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 boobytrapped for harassment.

140. Use of Nuclear Weapons

a. General. Atomic demolition munitions (ADM) may also 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 to other effects.

b. Atomic Demolition. Primary employment of ADM in tactical operations is normally for the production of obstacles. In retrograde movements their destruction and denial capability assumes major importance.

141. Reconnaissance

a. General. Thorough reconnaissance is necessary before an effective plan can be made to demolish an object. Thorough reconnaissance provides information in all factors related to the project.

b. Information Required. The following information needed for the demolition of bridges and culverts, and for road crater sites, should be obtained during reconnaissance.

(1) A situation map sketch should be made (fig. 92). It should show the relative position of the objects to be demolished, the surrounding terrain features, and the *coordinates of the object* on existing maps.

(2) A side-view sketch of the object to be demolished should be drawn (fig. 92). If, for example, a bridge is to be blown,

DEMOLITION RECONNAISSANCE RECORD (FM 5-25)					
SECTION I - GENERAL					
1. FILE NO.	2. DML RECON REPORT NO.		3. DATE		4. TIME
	NAME		GRADE	ORGANIZATION	
5. RECON ORDERED BY					
6. PARTY LEADER					
7. MAP REFERENCE					
8. SITE AND OBJECT		9. TIME OBSERVED	10. LOCATION		
11. GENERAL DESCRIPTION					
12. NATURE OF PROPOSED DEMOLITION					

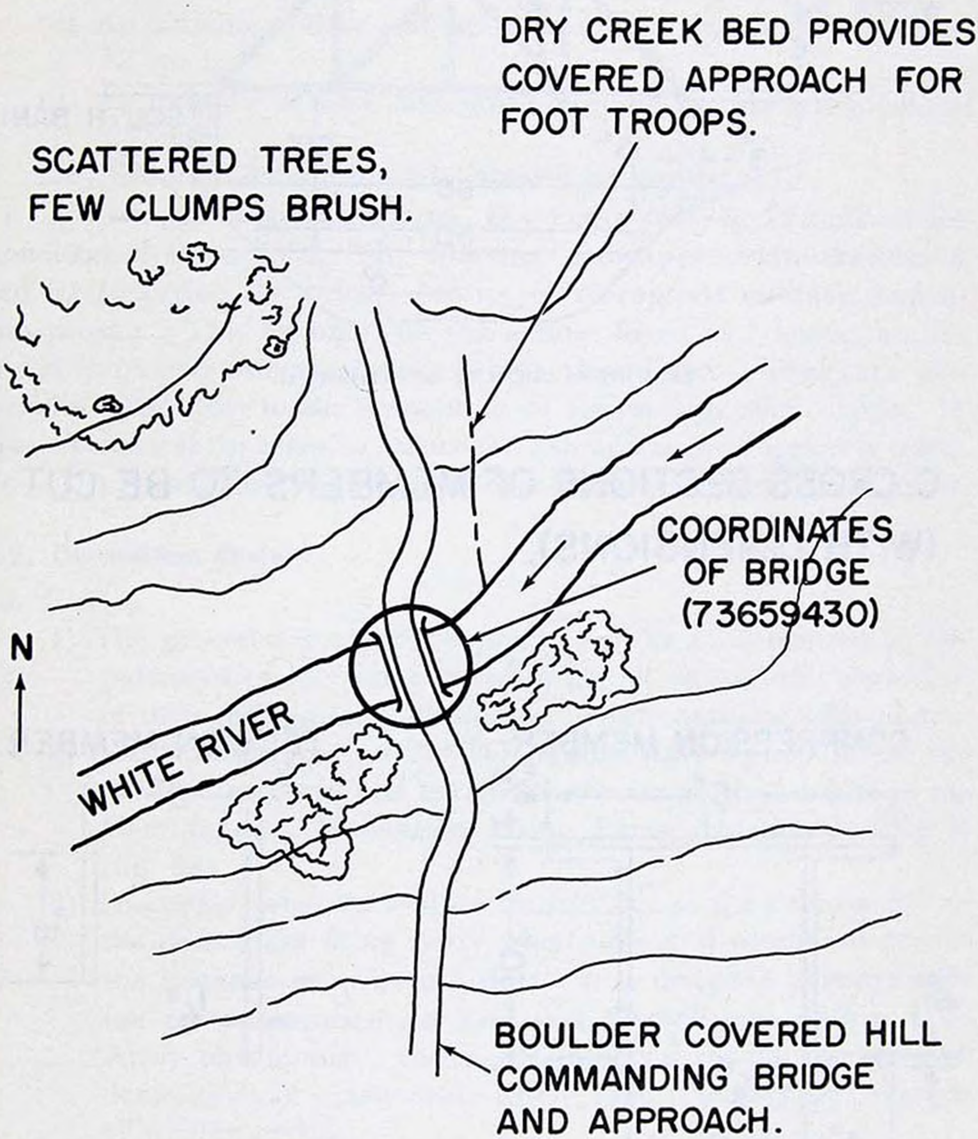
SECTION II - ESTIMATES*				
13. EXPLOSIVES REQUIRED				
a. TYPES	b. POUNDS	c. CAPS Electric	CAPS Non-Electric	d. DETONATING CORD (Ft.)
14. EQUIPMENT REQUIRED				
15. PERSONNEL AND TIME REQUIRED		PERSONNEL		TIME

SECTION III - REMARKS
16. UNUSUAL FEATURES OF SITE
17. LABOR AND TIME ESTIMATE REQUIRED FOR BYPASS
*Determine availability of Items 13, 14, and 15 before reconnaissance.
NOTE: Attach sketches as indicated in Figures 92A, B, and C, FM 5-25.

DA FORM 2203-R, 1 APR 59

Figure 92. Demolition reconnaissance record.

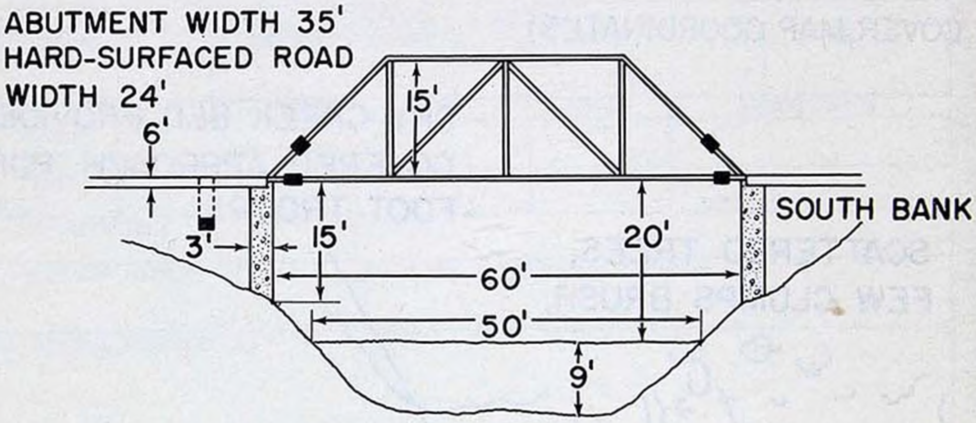
A. SITUATION MAP SKETCH.(INCLUDE PRINCIPAL TERRAIN FEATURES; IMMEDIATE AVENUES OF APPROACH; OBSERVATION AND COVER; MAP COORDINATES).



Situation map sketch.

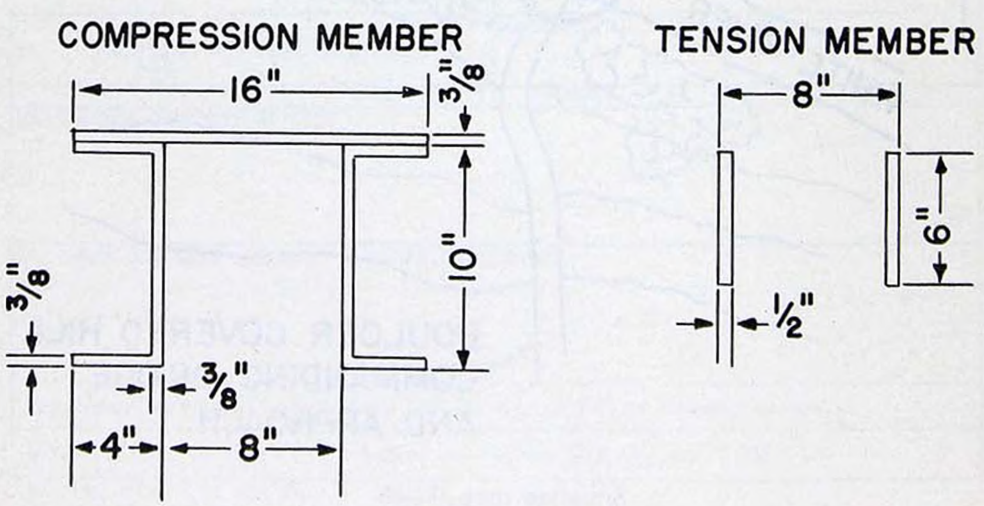
Figure 92—Continued.

B. LINE DRAWING OF OBJECT TO BE DEMOLISHED.(SHOW CRITICAL OVERALL DIMENSIONS AND PLACEMENT OF CHARGES).



Drawing of object to be demolished.

C. CROSS-SECTIONS OF MEMBERS TO BE CUT (WITH DIMENSIONS).



Cross-sections of members to be cut (with dimensions).

Figure 92—Continued.

a sketch of the bridge, showing overall dimensions of critical members, is necessary.

(3) Cross-section sketches should be made (fig. 92). They should contain relatively accurate dimensions of each member to be cut.

(4) A bill of explosives should be made. It should show the quantity and kind of explosives required.

(5) The firing circuits to be used should be sketched.

(6) All equipment required for the demolition should be listed.

(7) Unusual features of the site should be listed.

(8) An estimate of time and labor required to bypass the site should be made.

(9) An estimate of time and labor required for demolition should be made.

(10) Security details required should be estimated.

c. Demolition Reconnaissance Record. DA Form 2203–R, Demolition Reconnaissance Record (fig. 92), together with appropriate sketches is used for reporting the reconnaissance of a proposed military demolitions project. This format, and the actions listed in *b* 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 reconnaissance form should be appropriately classified. DA Form 2203–R will be reproduced locally on 8 × 10½ inch paper.

142. Demolition Orders

a. General.

(1) The procedures contained herein will be implemented as Department of the Army doctrine for all Army units regardless of their geographical disposition or international affiliation.

(2) The armed forces of NATO nations have agreed to use the procedures contained herein for the issuance of orders to the Commander, Demolition Firing Party, DA Form 2050–R (fig. 93).

(3) The order provides written instructions to the commander of the demolition firing party when time and conditions permit the issuance of written orders. It is designed primarily for use on preplanned or Reserved Demolitions within U.S. Army terminology, and is not intended for use on hasty or demolitions of opportunity where time prohibits the issuance of written orders.

b. Action by Commanders. Each commander responsible for controlling a Reserved Demolition (as defined in paragraph 17*c*, FM 31–10) is the issuing authority for Orders to the Commander, Demolition Firing Party. He—

(1) Establishes a clear-cut channel whereby the order to fire the demolition is transmitted from himself to the commander of the demolition firing party.

SECURITY CLASSIFICATION

ORDERS TO THE COMMANDER, DEMOLITION FIRING PARTY			SERIAL NO.
NOTES:—Parts I, II and III will be completed and signed before this form is handed to the commander of the Demolition Firing Party. Pars. 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

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 PAR. 4d AND WILL BE RECORDED BELOW.

STATE OF READINESS ORDERED "1(SAFE)" OR "2(ARMED)"	TIME AND DATA 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 par. 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 sub-par of pars. 4 and 5 which are not applicable. When there is a demolition guard sub-par. 4d will always be used, and par. 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 PAR. 6 BELOW.

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

5. YOU WILL NOT FIRE THE DEMOLITION IN ANY CIRCUMSTANCES EXCEPT AS ORDERED IN PAR. 4 ABOVE.
OR
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

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 par. 13).

SIGNATURE OF OFFICER ISSUING THESE ORDERS	NAME (In capitals)	TIME OF ISSUE	DATE OF ISSUE
	DESIGNATION		

PART IV—ORDER TO FIRE

8. BEING EMPOWERED TO DO SO I ORDER YOU TO FIRE NOW THE DEMOLITION DESCRIBED IN PAR. 1.

SIGNATURE	NAME (In capitals)	TIME	DATE
	DESIGNATION		

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 ENSURE 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 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 PAR. 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 PAR. 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 OVER-RIDING AUTHORITY OF WHOEVER GIVES YOU THESE NEW ORDERS, AND YOU WILL GET HIS SIGNATURE IN PAR. 8 WHENEVER POSSIBLE.
13. THE REPORT TO YOUR UNIT COMMANDING OFFICER, AS CALLED FOR IN PAR. 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 THE CASE OF A BRIDGE
  NUMBER OF SPANS DOWN)
  SIZE AND LOCATION OF CRATERS IN A ROAD OR RUNWAY.
  MINES LAID.
 e. SKETCH SHOWING EFFECT OF DEMOLITION.

SECURITY CLASSIFICATION

Figure 93. DA Form 2050-R, Orders to the Commander, Demolition Firing Party.

(2) Insures that this channel is known and understood by all concerned.

(3) Insures positive, secure means for transmitting the order to fire.

(4) Determines the necessity for a demolition guard, and if needed, allots responsibility to same.

(5) Specifies whether the demolition guard commander (or the commander of the demolition firing party if there is no demolition guard) is authorized to fire the demolition on his own initiative if the enemy is in the act of capturing it.

c. Orders to the Commander, Demolition Firing Party. Each commander who controls a Reserved Demolition (issuing authority) is responsible for completing Parts I, II, and III of DA Form 2050–R, "Orders to the Commander, Demolition Firing Party." He completes the order as required in regard to general and specific information, as follows:

(1) *General—Part I.*

(*a*) *Serial numbers.* When deemed necessary, serial numbers are to be assigned to Reserved Demolitions. When assigned, a system will be used that eliminates any possibility of confusion with other projects.

(*b*) *Security classification.* Security classification (if any) is determined by the issuing authority.

(*c*) *Code word of demolition target.* If desirable, a code word is assigned the demolition target by the authority issuing these orders.

(*d*) *Photographs and technical instructions.* Commanders are to attach photographs and special technical instructions if deemed necessary for completion of the project.

(2) *Specific—Parts I, II, and III.*

(*a*) *Description.* A thorough description of the target is given so that it is unmistakably identifiable.

(*b*) *Location.* The exact location of the target is given. Reference is made to the proper map name and scale, sheet number, and grid reference.

(*c*) *The demolition guard.* In the event a Demolition Guard (as defined in paragraph 2*j*, FM 31–10) is provided, the unit designation is given.

(*d*) *State of readiness.* The desired state of readiness, time, and date are given. The states of readiness are defined as:

1. "1 (Safe)." Demolition is safe against premature firing. All charges are prepared and securely fixed to target, and all firing circuits are complete, but not connected. Detonators (if used) have not been connected with charges.

2. "2 (Armed)." Demolition is ready for immediate firing. (Risk of premature firing is accepted.) Charges have been prepared and are securely fixed to the target, and all firing circuits have been connected to a means of firing.

Note. Any changes in the State of Readiness will be recorded in paragraph 3 of the Orders to the Commander, Demolition Firing Party.

(*e*) *Orders for firing.* When a demolition guard is assigned, the officer initiating this order designates the commander of the demolition guard as the officer signing the actual order to fire the demolition. If demolition guard is not assigned, the officer initiating the demolition order may—

1. Designate another officer to give the actual order to fire.

2. Direct the commander of the demolition firing party to fire the demolition as soon as it has been prepared.

3. Direct the commander of the demolition firing party to fire on receipt of the code word.

4. Specify to the commander of the demolition firing party a definite hour and date on which the demolition is to be fired.

(*f*) *Orders for reporting.* The commander responsible for issuing these orders signs and completes paragraph 7.

d. General Instructions.

(1) *Order to Fire (Part IV).* This section is completed by the officer authorized to order the firing of the demolition. It will be signed by the commander of the demolition guard, the officer initiating the order, or the authorized representative of the officer initiating the order.

(2) *Reporting.* After firing the demolition, the commander of the demolition firing party immediately reports the results to the officer who ordered the firing. This may be the commander of the demolition guard, the officer initiating the demolition order, or any officer so designated by him. In addition, the commander of the demolition firing party will report the results to his unit commander. The report should contain the following information (where applicable):

(*a*) Identification reference of demolition (target and code name).

(*b*) Map reference.

(*c*) Time and date when demolition was fired.

(*d*) Extent of damage accomplished, to include sketch showing effect.

(3) *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.

CHAPTER 8

BRIDGE DEMOLITIONS

Section I. MAJOR CONSIDERATIONS IN BRIDGE DEMOLITIONS

143. General

a. Extent of Demolition To Be Accomplished. Bridges are generally demolished to create obstacles that will cause the enemy a tactical delay. This will seldom require the complete destruction of a bridge. Unless a scorched-earth policy is in effect the method of demolition chosen should be one which will permit economical reconstruction of the bridge by friendly troops at a later date, but still achieve the required tactical delay. This can be accomplished by creating a gap in the bridge longer than can be spanned by whatever prefabricated bridging is available to the enemy. The gap should be made where pier construction is difficult, thus preventing the enemy from easily building an intermediate pier to facilitate the use of prefabricated bridging. Factors governing the extent to which destruction should be planned are as follows:

(1) The tactical, strategical, and political situations which indicate the length of time the enemy must be delayed; the time available for demolition; and the extent of denial to be accomplished.

(2) The likelihood that friendly forces may reoccupy the area and require the bridge.

(3) 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.

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

b. Complete Demolition. Complete demolition of a bridge results in leaving nothing of the old bridge suitable for use in a new bridge and necessitates building a new structure at another site, thus nullifying the utility of the structure and approaches. This can best be accomplished by leaving debris where its removal will require a large amount of hazardous work before any kind of crossing can be developed on the site. It should be borne in mind that a permanent structure is not likely to be replaced in kind during wartime. 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. Where the topography is such that the existing bridge site is needed for any new structure, even a temporary one, demolition in greater detail may be justified.

c. Economical Demolition. The best points of charge application and the necessary quantities of explosives for demolition are dictated by the individual structure. Where the superstructure can be cut to fall over the substructure in such a manner as to destroy the usefulness of both, no effort should be expended on the substructure. The most economical way to demolish high and relatively slender superstructures is to cut one side so that the entire structure topples into a mass of broken and twisted material. Destruction of massive abutments or other substructure involves large expenditures of explosives, time, equipment, and effort. If the abutment of a major bridge can be easily replaced its demolition may not be justifiable.

d. Planning a Bridge Demolition. The following general points apply to most or all of the structures described below. They should be borne in mind when planning bridge demolitions.

(1) An individual qualified in bridge design and construction is best qualified to plan the demolition of bridges. Particularly in the case of large complex structures, such a person should be sought out to plan, or to assist in planning, demolitions. However, if this is not possible, persons not qualified to design or to construct bridges can accomplish successful demolitions by using the instructions which follow.

(2) Where hasty charges must be placed first because of possible enemy interruption, careful placement of those charges may allow them to be later incorporated into the deliberate preparation of the bridge.

(3) It is almost always 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 the situation permits, this course of action should be considered.

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

(5) When it is intended to drop a length of the superstructure of a bridge, the lines of breaching or cutting should slant upward toward the section which is to be dropped so that it will not become entangled on the remainder of the structure. Piers or bents should be cut on an angle so that they will tend to slide apart or overturn sideways, thereby further displacing the superstructure.

(6) When bridges over railways or canals are being demolished, the demolition should be so planned that any temporary in-

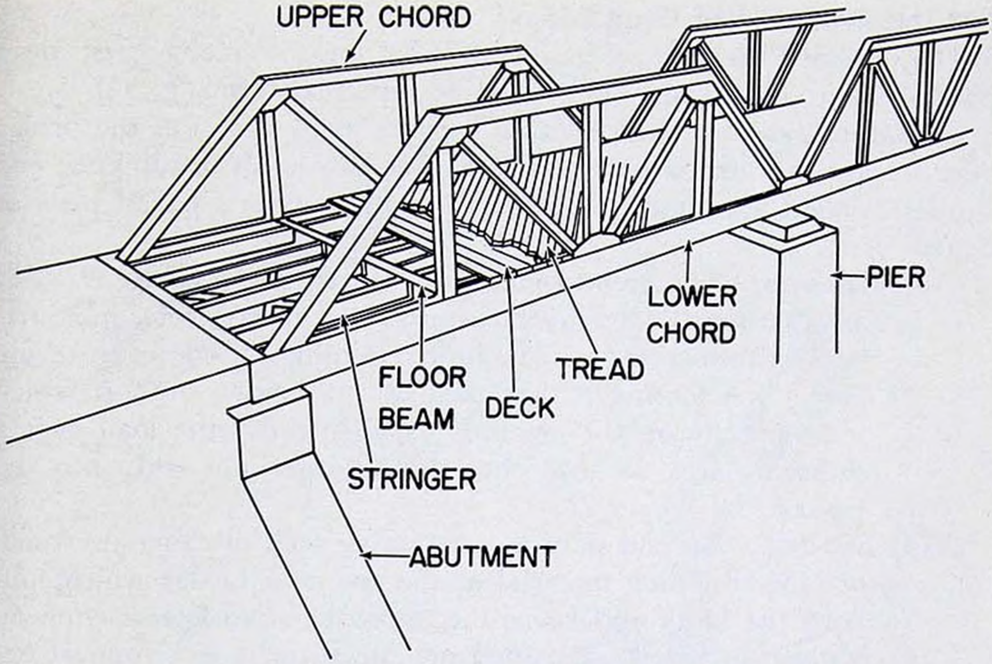


Figure 94. Nomenclature of fixed bridges.

termediate piers which might be erected to repair the structure must be located where they will block traffic on the railroad or canal.

(7) Any long steel members that need to be cut 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 placed so as to damage the upper flange in some places, and the lower flange and the web in others, will make repair difficult and uneconomical. Twisting such members in dropping the span and using a gas-cutting torch should also be considered.

(8) Sometimes the height of a trussed structure and the distance it can drop make an intended twisting action uncertain. The structure can be forced to twist by cutting one truss completely through at approximately the third points, while cutting the other truss almost through at the same points, leaving intact only the top chord of the second truss.

(9) Internal breaching charges offer a large economy in the amount of explosives required, but generally they require a longer time to prepare. Whether or not it is advisable to use them depends on the relative value of explosives, time, manpower, and equipment availability.

(10) The nature of the terrain on which the debris is to fall is of considerable importance to the success of the demolition. When possible, advantage should be taken of the weight of the structure to assist in its own destruction.

144. Nomenclature of Fixed Bridges

The ordinary fixed bridge can be divided into two main parts: lower part or substructure, and upper part or superstructure (fig. 94).

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

(1) *Abutment.* The ground support at the ends of a bridge is called an abutment. It 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 which rests directly on the ground. It distributes the load over a sufficient area so that the support does not sink into the ground.

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

(4) *Intermediate support.* An intermediate support is a support 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, the stringers, the floor beams, and any girders or trusses which make up the total part of the bridge above the substructure (fig. 94).

(1) *Lower chords.* Lower chords are the lower members in a panel of a truss which run parallel to the deck.

(2) *Upper chords.* Upper chords include the upper members in the panel.

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

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

145. Destruction of Concrete and Masonry Abutments

a. General. Abutments can be destroyed by either internal or external breaching charges, as described in paragraphs 125 through 127. Abutments can also be destroyed by charges placed in the fill behind them. Charges placed in the fill behind an abutment will generally be more efficient but will be more difficult to place. With any method, sufficient explosives must be used to demolish the entire width of the abutment. Demolition of abutments is especially effective where the topography forces the enemy to use the existing site for a new abutment.

b. Charges in Fill Behind Abutment.

(1) *General.* Placing charges in the fill behind an abutment offers the advantages of economical use of explosives and of concealment of the charges from the enemy until they are detonated. This method has the disadvantage that the charges are difficult to place. Where speed is essential, charges are

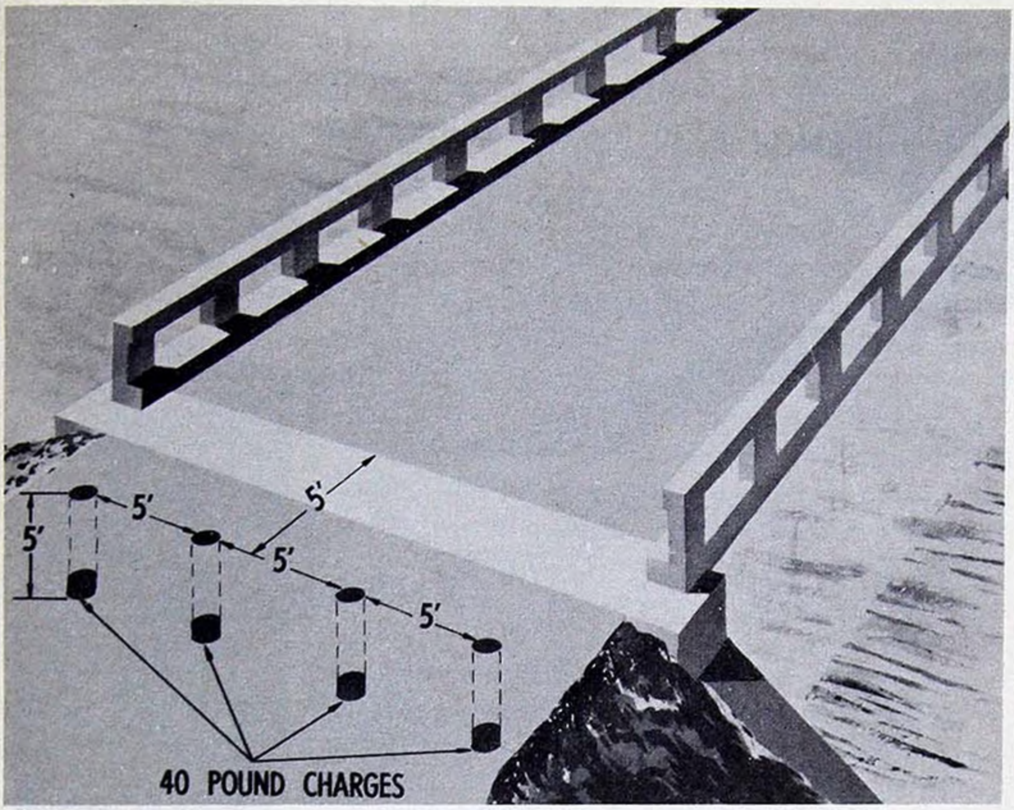


Figure 95. Charges placed in the fill behind a reinforced concrete abutment less than 5 feet thick.

not used behind the abutment if it is known that the fill contains large rocks. Power earth augers are ineffective in rocky soil, and hand excavation is slow. 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.

(2) *Abutments 5 feet or less in thickness.* Abutments 5 feet or less in thickness are demolished by a line of 40-pound cratering charges on 5-foot centers, placed in holes 5 feet deep and 5 feet behind the face of the abutment (fig. 95). The first hole is placed 5 feet from one side of the road, and this spacing is continued until 5 feet or less is left from the last hole to the other side of the road. If the wing walls are sufficiently strong to support a bridge in rebuilding, they too should be destroyed by placing charges behind them in a similar fashion.

(3) *Abutments more than 5 feet thick.* Abutments more than 5 feet thick are destroyed by breaching charges placed in contact with the rear face of the abutment (fig. 96). Charges are calculated by the breaching formula, $P=R^3KC$ (par. 125*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 calculations explained in paragraphs 125 and 126.

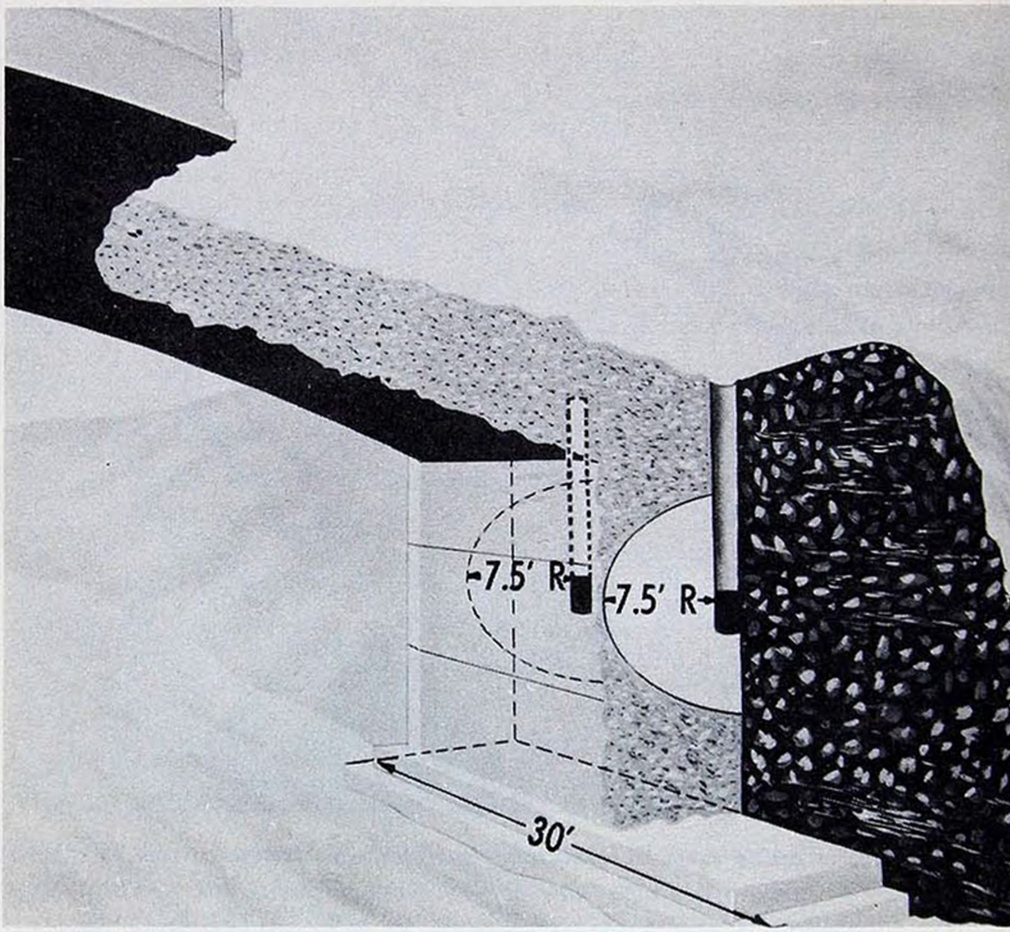


Figure 96. Two charges in the fill behind a reinforced concrete abutment more than 5 feet thick.

c. 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 charges in the fill behind the abutment. These fill charges may be breaching charges as explained in paragraph 145*b*(3) or as explained in paragraph 145*b*(2), depending on the abutment thickness. This tends to overturn and completely destroy the abutment.

146. Destruction of Intermediate Supports

a. General. The destruction of one or more intermediate supports of a multispan bridge is usually the most effective method of demolition. The demolition 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. This will require either the replacement of those supports or the construction of long spans when the bridge is repaired.

b. Concrete and Masonry Piers. Concrete and masonry piers are demolished either by internal or external charges. Internal charges are more effective and require less explosive than external charges, but internal charges require a great amount of equipment and time for preparation. For this reason they are seldom used unless explosives are scarce or unless the pier has built-in demolition chambers. The number of charges required is calculated by the formula $N=\frac{W}{2R}$ (par. 125*b*). The size of each charge is calculated by the breaching formula, $P=R^3KC$.

(1) *Internal charges.* Plastic explosives, dynamite, and other explosives which may be tightly compressed are most satisfactory for internal charges. All charges should be thoroughly tamped with blunt wooden tamping sticks. Charges *are not* tamped with steel bars or tools. When no demolition chambers exist, charges are placed in boreholes, which are blasted with shaped charges or drilled with pneumatic or hand tools. A 2-inch diameter borehole holds about 2 pounds of tightly compressed explosive per foot of borehole length or depth. The steel reinforcing bars make drilling in heavily reinforced concrete impracticable.

(2) *External charges.* External charges are placed at the base of a pier and are spaced not more than twice the breaching radius (par. 125*b*) apart. When only one breaching charge is required, it is placed against the center of the base of the pier. All external charges should, if time permits, be thoroughly tamped with earth and sandbags.

c. Bents and Piers. The destruction of the bents or piers on large bridges takes a considerable length of time because effective demolition of them requires that each individual post or pile be cut. These cuts should be made below the waterline whenever possible. The charges for these cuts are computed with the following formulas:

(1) For steel $P\text{ (TNT)}=\frac{3}{8}A$, or $P(C4)=0.3A$ (par. 114).

(2) For timber $P(\text{TNT})=\frac{D^2}{40}$, $P(\text{TNT})=\frac{D^2}{250}$, or $P(C4)=\frac{D^2}{50}$ (par. 118).

147. Destruction of Fixed Bridge Superstructures

a. General. Fixed bridges are the most common type of bridges and include the greatest variety of superstructures. With few exceptions fixed bridges are built of steel, timber, or concrete.

b. Common Types of Superstructures. A fixed bridge is usually identified by its type of superstructure. Stringer, slab, truss, arch, and suspension type fixed bridges are those most likely to be found in any theater of operations.

c. Placement of Charges. Charges on deck structures are usually placed under the bridge roadway (fig. 97) unless time demands that a pressure charge be used (par. 121). This involves working from ladders or scaffolding. Ladders are insecure, restrictive, and impractical over water. A scaffolding hung from the bridge rail or curb is quickly made and easily moved. Material can then be handled from the

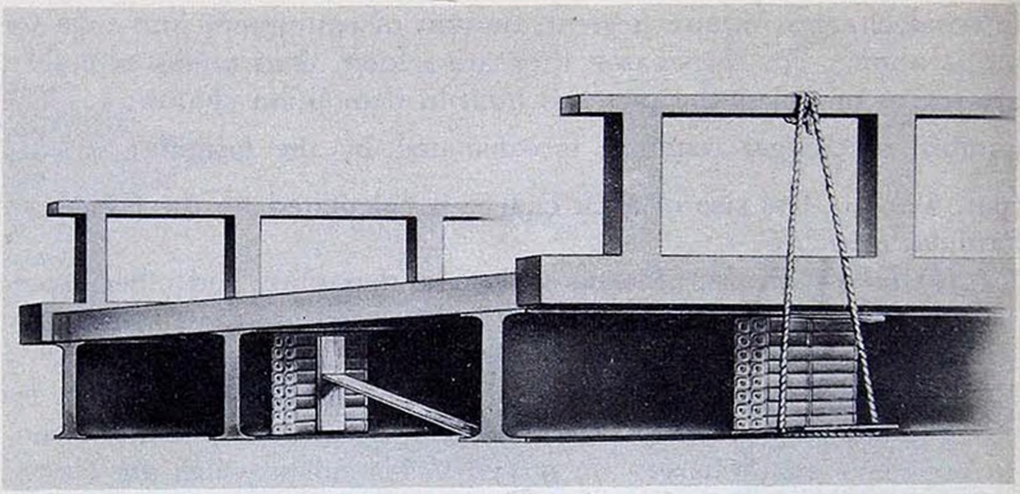


Figure 97. Placement of charges for demolition on a steel stringer bridge.

roadway, from the ground, and from a boat. One or both ends can be let down, and the scaffolding can be moved around piers and bents in order to work on successive spans.

d. Safety Precautions. Special precautions must be taken to insure that the charges will not be initiated by traffic on the bridge. When a complete electrical firing system is placed on a bridge, signs or guards should be used 100 feet or more from the bridge to warn friendly users to turn off mobile transmitters.

Section II. SPECIFIC BRIDGE DEMOLITION

148. Stringer Bridges

a. General. The stringer bridge is the most common type of fixed bridge in most parts of the world. It is frequently used in conjunction with other types of spans. The stringers are the load-carrying members; the floor is dead load so far as the stringers are concerned. 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 cutting charges on each stringer. The stringers should be cut into unequal lengths so as to hinder salvage (fig. 98).

c. Continuous Spans. Continuous spans have beams which extend over more than two spans. Because these spans are stiffer over piers than at midspan, they may frequently remain in place even though completely cut in midspan. Steel or reinforced concrete are commonly used for such beams. Continuous steel beams, girders, or trusses may be identified by the fact that they are the same depth, or deeper, over piers as elsewhere, and because there is no break or weak section over the supports. The superstructure may be demolished by cutting *each member* in *two* places *between supports* so as to drop completely the portion between cuts. Continuous concrete T-beam or continuous con-

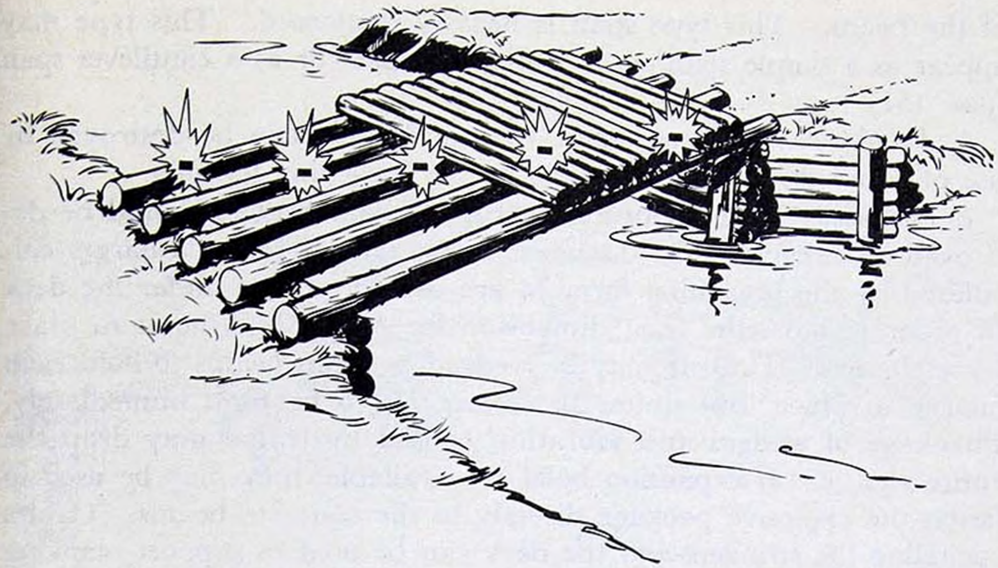


Figure 98. Charges placed to cut span of a timber stringer bridge.

crete slab bridges can be recognized by the absence of construction or expansion joints over the supports. Continuous T-beam bridges can also be recognized by the haunching or deepening of the section adjacent to the interior supports. Pressure charges at midspan on continuous concrete beams give unsatisfactory destructive results and should not be used (fig. 82). Such bridges should be attacked by demolishing the piers, by demolishing the junction between span and pier, or by removing all spans by cutting them at approximately one-quarter of their lengths from each end. Breaching charges are used in all these cases. Such charges may be placed on or underneath the roadway as is most convenient.

149. Slab Bridges

The superstructure of a slab bridge consists of a flat slab supported at both ends. These slabs are usually of reinforced concrete, but may be found constructed 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 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. When the breaching formula is used, the charges are placed twice the breaching radius apart. When the timber formula is used, the charges are placed twice the slab thickness apart. Continuous slabs may be recognized as discussed in paragraph 148*c*. Continuous slab spans must be cut in two places to insure dropping the slab.

150. T-Beam Bridges

a. General. A T-beam bridge is essentially a concrete stringer bridge, but the floor and stringer are of one piece and the floor acts as part of the beam. This type span is heavily reinforced. This type may appear as a simple span, as a continuous span, or as a cantilever span (par. 151).

b. Simple Span. Simple span T-beam bridges can be destroyed by use of either the pressure formula or the breaching formula.

c. Continuous Span. Continuous span T-beam bridges should be destroyed by breaching, as discussed in paragraph 148*c*. Charges calculated by the breaching formula are usually placed under the deck in order to have the least dimension for *R*. It is difficult to place these charges. Timbers may be wedged between beams to hold each charge in place, but unless the charge is to be fired immediately, shrinkage of wedges and vibration caused by traffic may drop the entire charge. If expansion bolts are available, they may be used to fasten the explosive package directly to the concrete beams. Cables encircling the stringers and the deck can be used to support planking beneath the bridge, and the charges may be secured on this supported planking (fig. 99). Such an arrangement need not interrupt traffic prior to blowing the bridge.

151. Concrete Cantilever Bridges

a. General. Concrete cantilever spans can be recognized by the construction joints that appear in the span and not over the piers. The bridges may or may not contain suspended spans. Figure 100 shows a cantilever bridge with a suspended span, and figure 101 a cantilever bridge without a suspended span.

b. Concrete Cantilever Bridges With Suspended Span. The superstructure of a concrete cantilever bridge with suspended spans may be attacked by cutting each cantilever arm adjacent to the suspended span. If a large gap is desired, the cantilever arms should be cut so as to destroy the cantilever action, thereby dropping the cantilever arms and the suspended spans (fig. 100).

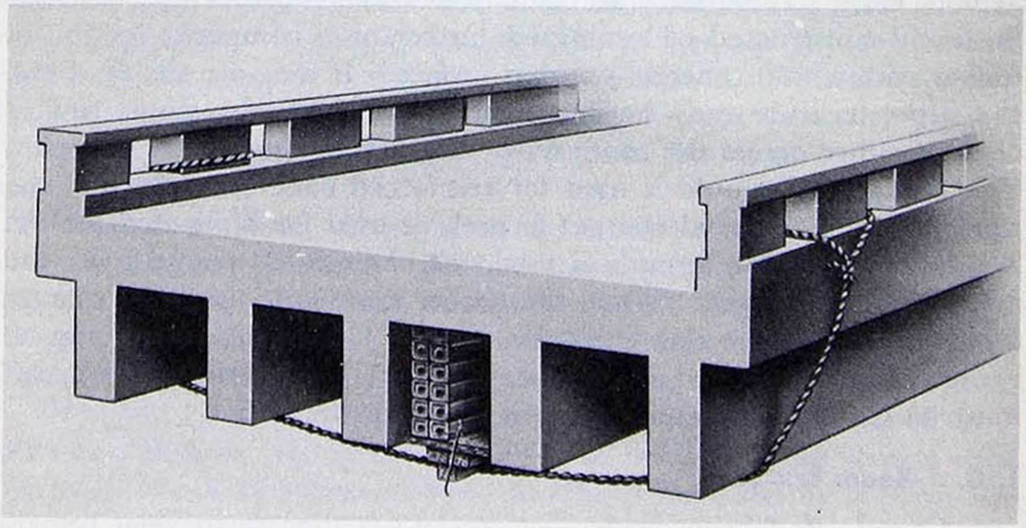


Figure 99. Method of supporting charge beneath a T-beam bridge.

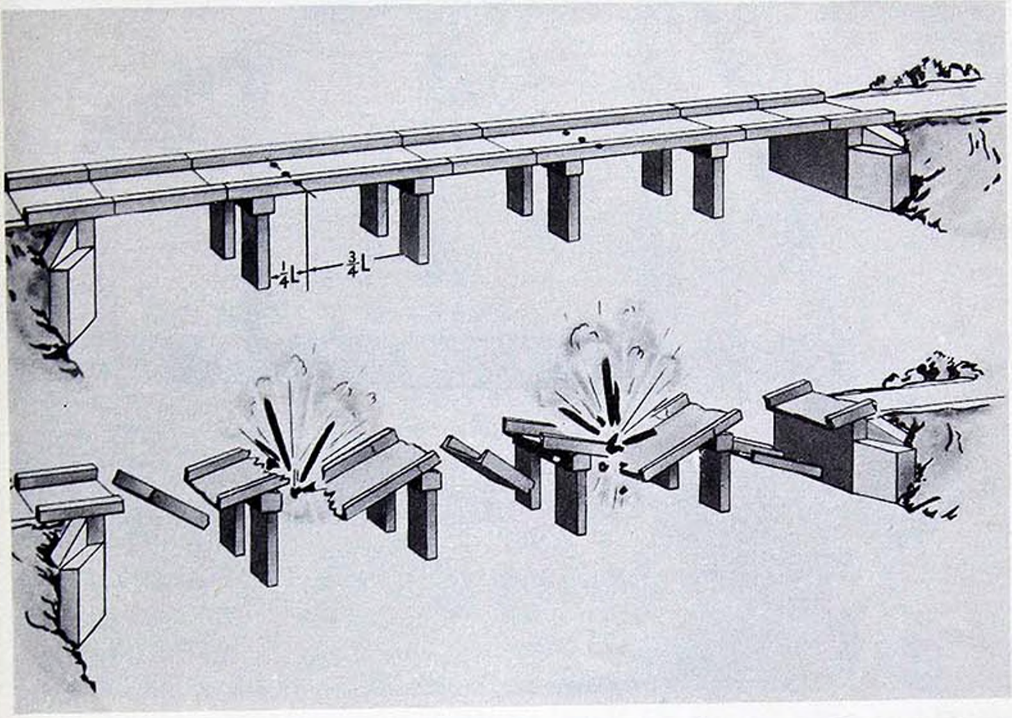


Figure 100. Placing charges on a concrete cantilever bridge with suspended span.

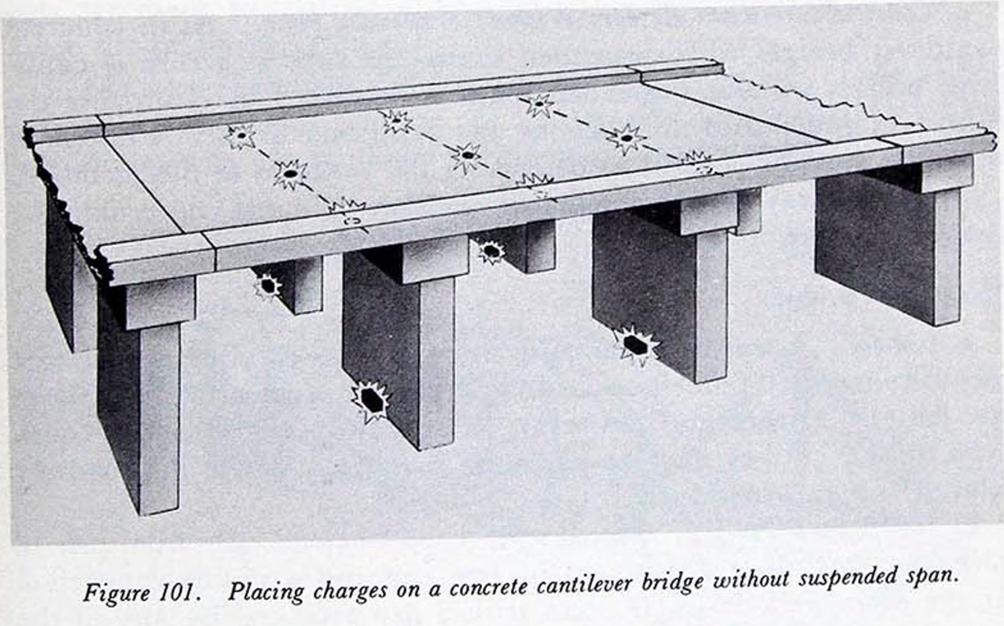


Figure 101. Placing charges on a concrete cantilever bridge without suspended span.

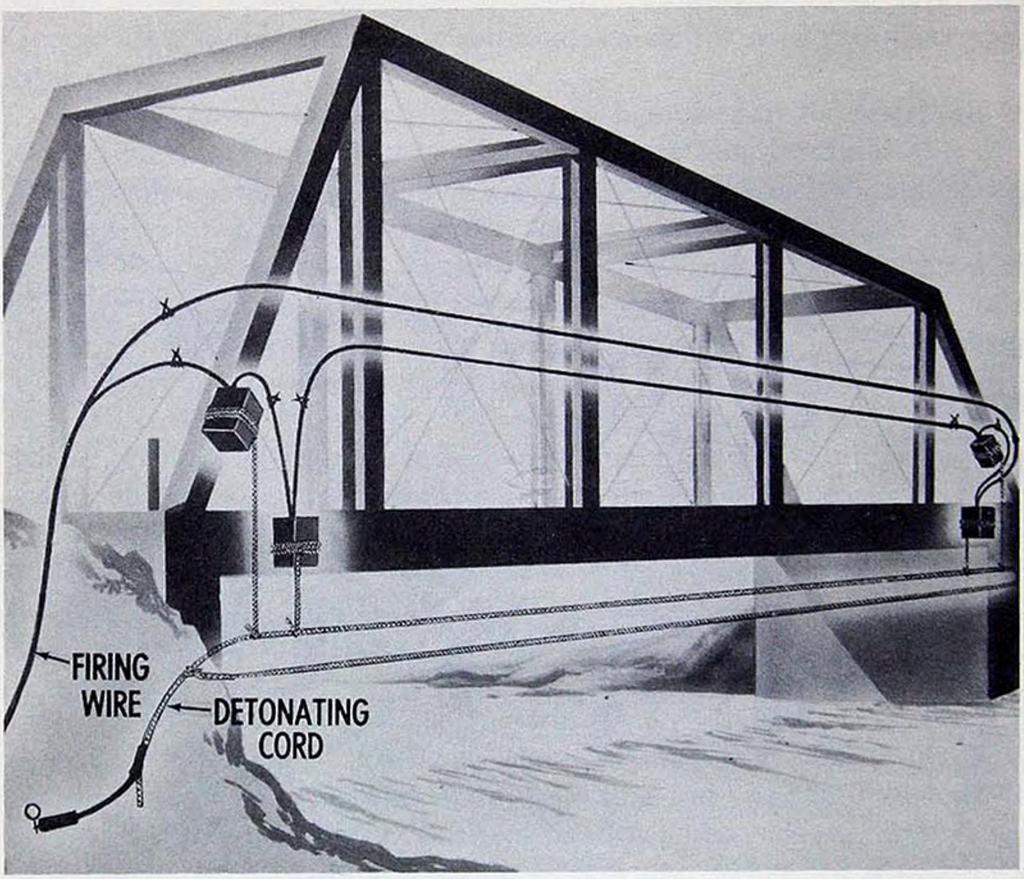


Figure 102. Steel truss bridge prepared for hasty demolition.

c. Concrete Cantilever Bridges Without Suspended Span. As in concrete cantilever bridges with suspended spans, the superstructure of cantilever bridges without suspended spans is destroyed by destroying the cantilever action and unbalancing the cantilever arms. A bridge of this type must be studied to determine the function of the members. Only in this way can an intelligent decision be made concerning the proper placement of charges.

152. Truss Bridges

a. General. 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 below the roadway of the bridge (deck type trusses) or they may be partly or completely above the roadway (through type trusses).

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

(1) The end posts and lower chords are cut at both ends of one truss in each span (fig. 102). This causes the bridge to roll over; thereby twisting the other truss off its support. If the

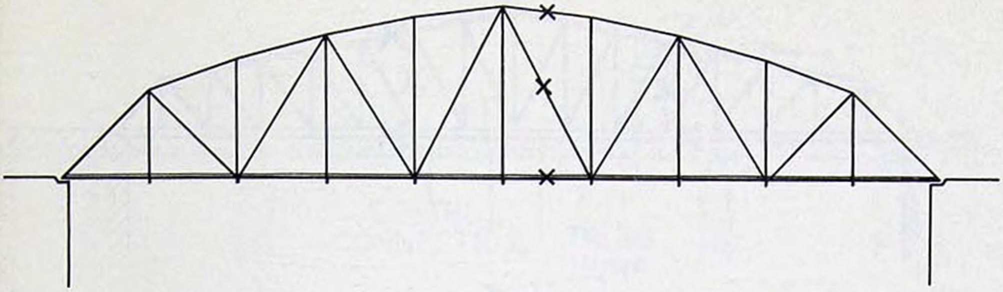


Figure 103. Placement of charges to cut upper and lower chords of truss.

truss is too small and too light to twist free, then both ends of both trusses on each span should be cut or the method described in (2) below should be used.

(2) The upper and lower chords of both trusses are cut at mid-span (fig. 103). Diagonal members which might prevent collapse should also be cut.

(3) Both trusses are cut into segments (fig. 104). This is a more complete demolition and makes salvage of the truss extremely difficult.

c. Continuous Span Trusses. Continuous span trusses are usually continuous over only two spans, rarely over three. The heaviest chord sections and the greatest depth of truss are over the intermediate supports. One method of demolition is shown in figure 105. In general, aside from continuity, the principles listed for simple span trusses are applicable to continuous spans. Care must be taken whenever the cuts are made so that an unbalanced condition remains which will cause the bridge to collapse.

d. Additional Destruction. If more complete destruction of the bridge is required, all trusses may be cut into smaller pieces after they have been dropped by the methods described in *b* and *c* above.

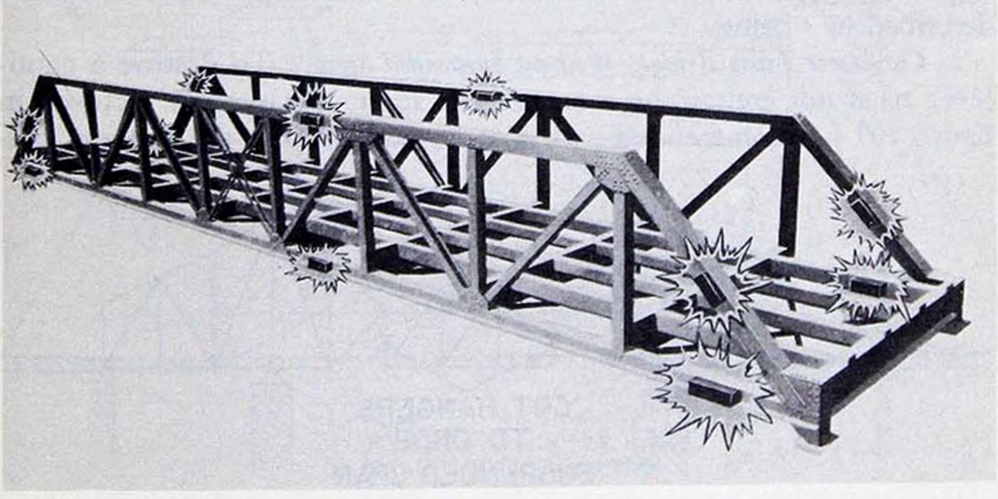


Figure 104. Placement of charges on a steel truss bridge to cut the trusses into segments.

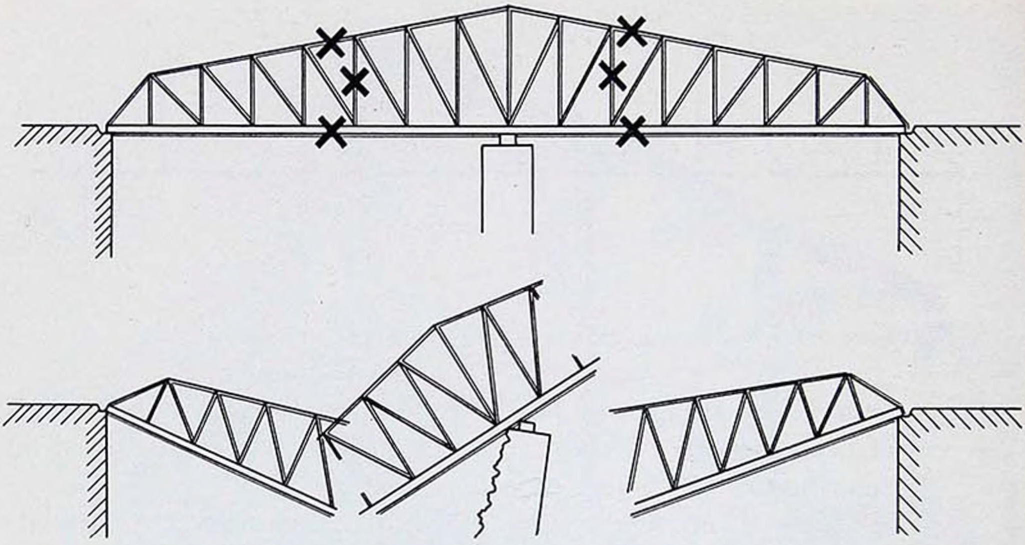


Figure 105. Placement of charges on a continuous span truss.

153. Cantilever Truss Bridges

a. General. Cantilever truss bridges derive their strength from a much deeper, stronger truss or beam section over the piers, having, in effect, two "arms" which reach partly or completely across the adjacent spans. Cantilever truss bridges are a modification or refinement of continuous truss or continuous beam bridges, and the principles given in paragraphs 150 and 152 for those types of bridges also apply to cantilever bridges.

b. Cantilever Truss Bridges With Suspended Span. Cantilever truss bridges with suspended spans are invariably major bridges, having suspended spans up to 700 feet long and single spans up to 1,800 feet long. The suspended span is hung from the ends of adjacent cantilever arms by means of hinges, hangers, or sliding joints. These spans may be dropped out of the bridge by cutting at these hinges, hangers, or joints (fig. 106). The cantilever arms may also be attacked 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 pictured in figure 107 is recommended. It is to be noticed that the top and bot-

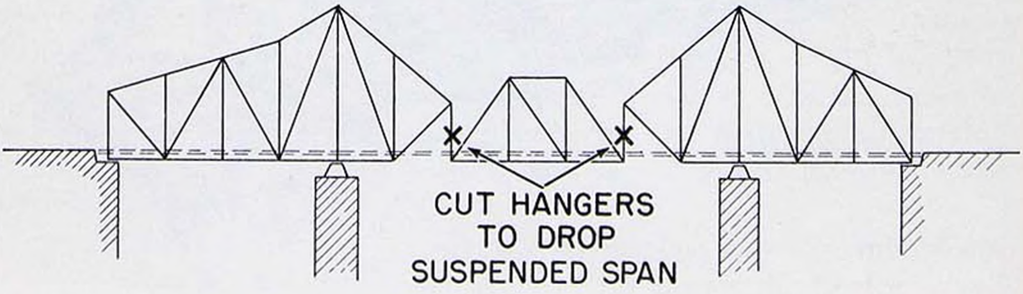


Figure 106. Demolition of a cantilever truss with suspended span.

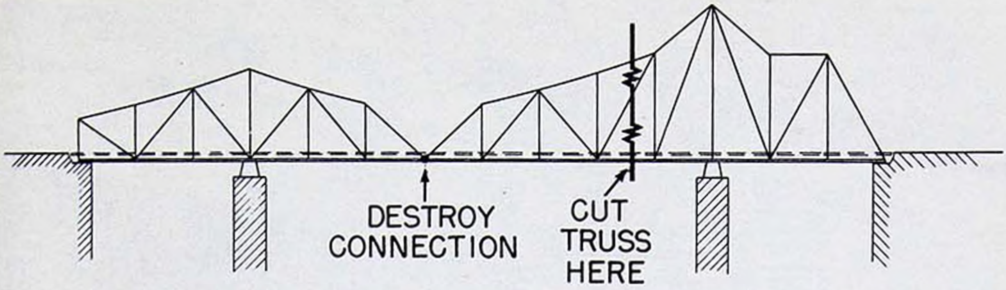


Figure 107. Demolition of a cantilever truss without suspended span.

tom chords are cut at any desired point, and that the bridge is also cut through near the joint at the end of the arm in the same span. Another method of accomplishing 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.

154. Destruction of Arch Span Bridges

a. Nomenclature of Arch Span. Since it is convenient to use certain technical terms in discussing the demolition of arches, a few of these terms are defined here and are shown in figure 108.

(1) *Span.* The horizontal distance from one support of an arch to the other support of the arch.

(2) *Rise.* The vertical distance measured from the horizontal line connecting the supports to the hignest point on the arch.

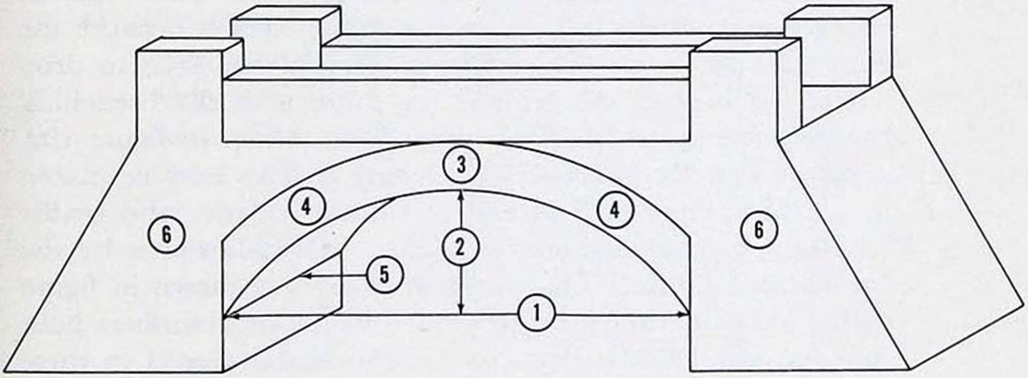
(3) *Crown.* The highest point on the arch.

(4) *Haunches.* Those portions of the arch which 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 Arches. A filled spandrel arch consists of a barrel



1 Span　　4 Haunches
2 Rise　　5 Spring lines
3 Crown　　6 Abutments

Figure 108. Nomenclature of arch span bridges.

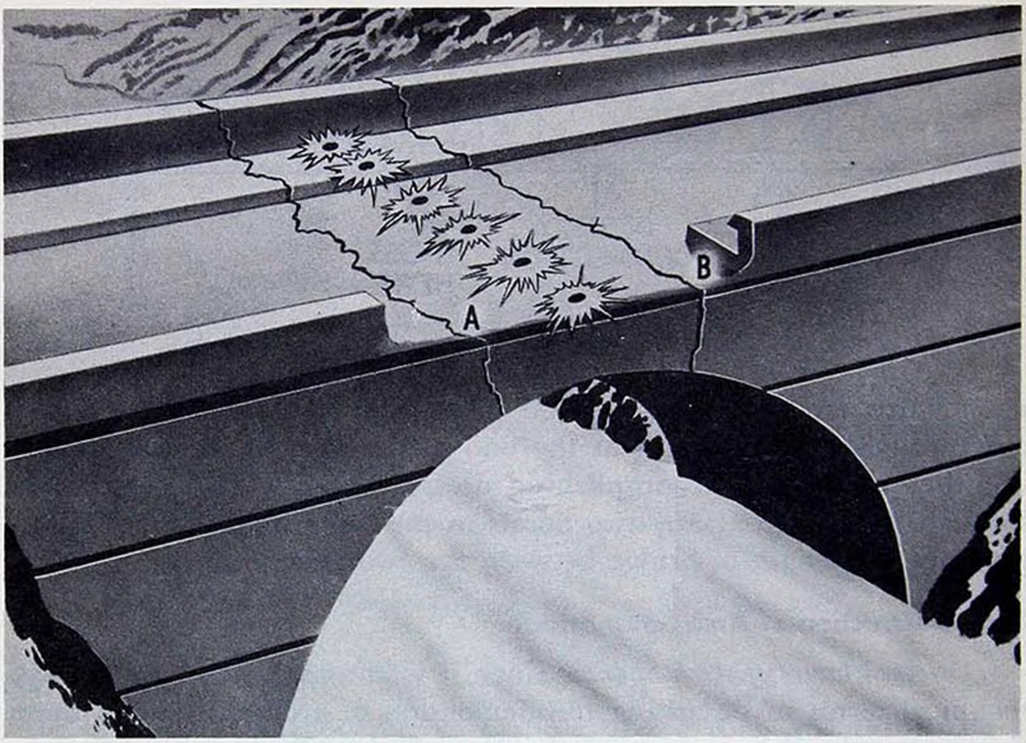


Figure 109. Placement of crown charges for breaching a filled spandrel arch bridge.

arch supporting an earth or rubble fill between retaining walls set on the edges of the arch. This arch is most vulnerable at its crown, where it is the thinnest. Here the earth fill is usually only a foot or two thick. Filled spandrel arches may be constructed of masonry (stone or brick), reinforced concrete, or a combination of these materials. These arches can be destroyed with either crown charges or haunch charges.

(1) *Demolition with crown charges.* Crown charges are more easily and quickly placed than haunch charges, but their effectiveness is substantially less. This is particularly true on an arch with a rise which is large in comparison to 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. Calculation is done with the breaching charge formula. Charges are placed as shown in figure 109.

(2) *Demolition with haunch charges.* Breaching charges may be placed at the haunches (just ahead of the abutment) and traffic maintained until demolition occurs. Calculation is by the breaching formula. Placement of charges is shown in figure 110. Many masonry bridges have vaults or chambers built into the haunches. The charges should be placed in these vaults if they are present. Their existence usually is revealed by ventilating brick in the side wall of the arch. Charges placed in one haunch would drop out that portion of the arch between lines C and D in figure 110. Charges in both

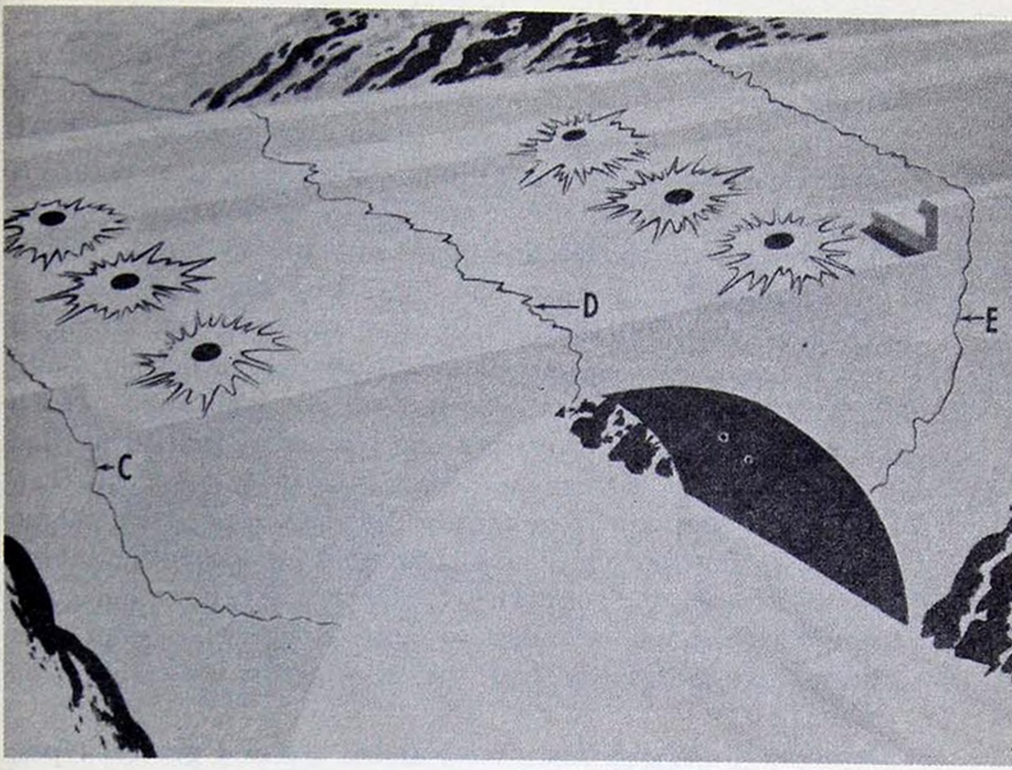


Figure 110. Placement of haunch charges for destroying a filled spandrel arch bridge.

haunches would drop out that portion of the arch between lines C and E (fig. 110).

c. Open Spandrel Arches. An open spandrel arch consists of a pair of arch ribs supporting columns or bents which in turn support a 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. Figure 111 shows a reinforced concrete open spandrel arch bridge. The open spandrel arch bridge may be constructed of reinforced concrete, steel, timber, or any combination of these materials.

(1) *Demolition of concrete open spandrel arch.* The ribs of a concrete open spandrel arch bridge (fig. 111) are usually about 5 feet wide, and 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. But here again the same difficulties will be encountered in reaching the working points at the crown as are experienced in T-beam (par. 150) or stringer (par. 148) bridges. The same type of scaffolding used on these other types of bridges can be used for placing demoli-

tion charges on this type of bridge. For structural reasons the bents over the abutments are most likely to be heavy. Hence 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 monolithic (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 result in the damaged bridge serving as an excellent support on which to build a new temporary bridge. To prevent any utilization of such a span, it is advisable to use one charge 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 should be computed for either the rib or the pillar over the support, whichever is greater. For short single arch spans, it is best to destroy the entire span with breaching charges behind the abutments or behind the haunches.

(2) *Demolition of steel arch span.* Steel arches are of 4 general types: continuous arches (1, fig. 112), one-hinged arches (2, fig. 112), two-hinged arches (3, fig. 112), and three-hinged arches (4, fig. 112). One-hinged arches are hinged in the middle; two-hinged arches are hinged at both ends; and three-hinged arches are hinged 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 buttresses to allow the arch to fall. Two-hinged and three-hinged arches need only one charge apiece for destruction. This charge should be placed at the center of the span.

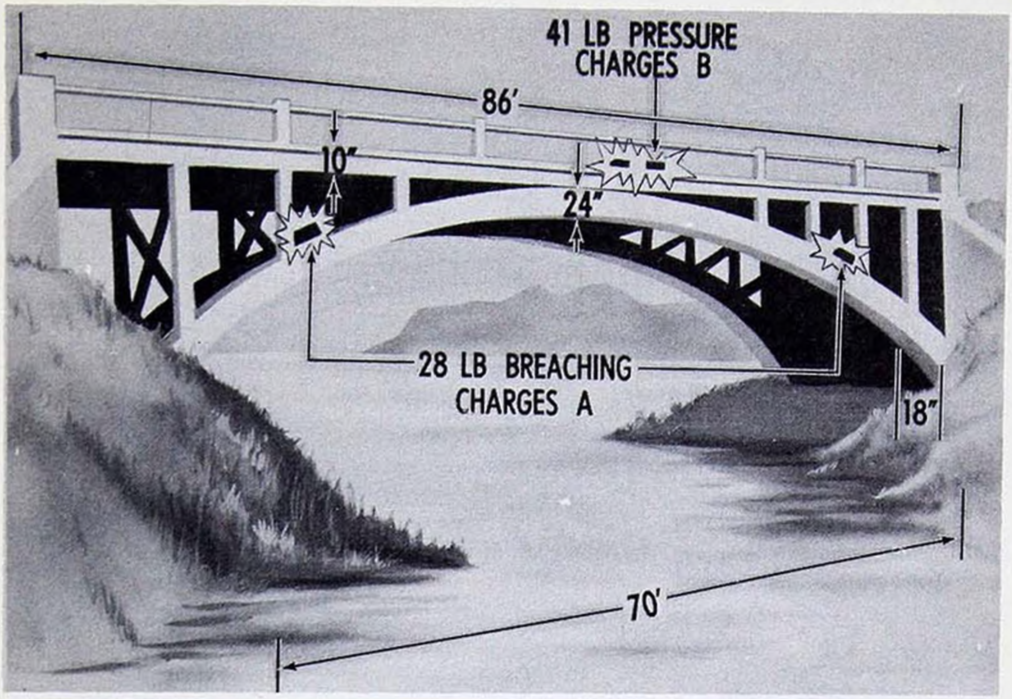
155. Suspension Spans

a. General. 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. The component parts of suspension bridges will first be described; then the demolition of these bridges will be discussed under two general headings, major structures and minor structures.

b. Component Parts.

(1) *Cables.* Cables of suspension bridges are usually two multiple-steel-wire members which 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 constructed of steel, concrete, or masonry.



CHARGE CALCULATIONS

BREACHING CHARGES

$P=R^3KC$ (par 125)
$R=2$ ft.
$K=0.70$ (table X)
$C=4.5$ (fig. 83)
$P=2^3\times0.70\times4.5=25.2$
Since P computes less than 50 pounds, add 10%
$P=25.2+2.5=27.7$
Use 28 pounds of TNT for each breaching charge.

PRESSURE CHARGES

$P=3H^2T$
$H=3$ ft.
$T=1.5$ ft.
$P=3\times3^2\times1.5=40.5$
Use 41 pounds of TNT for each pressure charge.

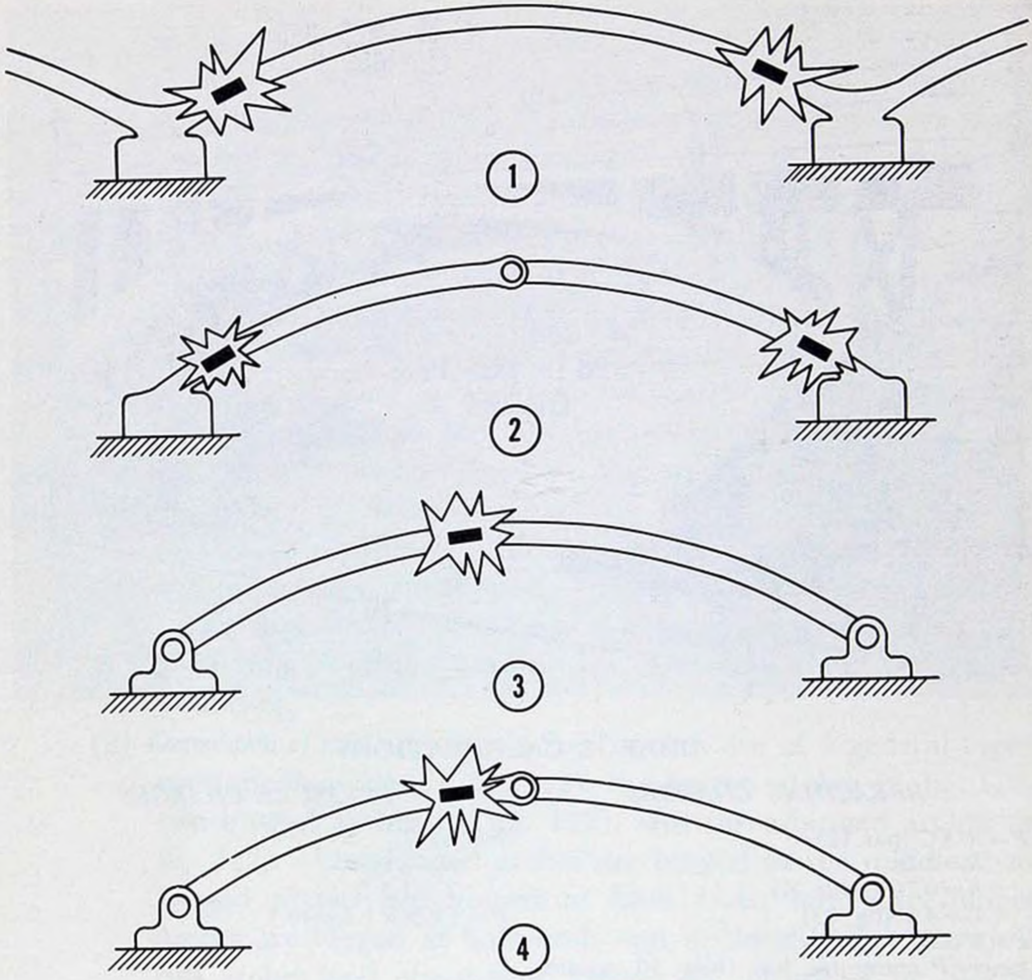
Figure 111. Placement for charges for demolition of a reinforced concrete open spandrel arch bridge.

(3) *Trusses or girders.* Trusses or girders of a suspension bridge do not support the load directly. They are provided for stiffening purposes only.

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

c. Destruction.

(1) *Major structures.* The towers and anchorages of a major suspension bridge are usually too massive to be destroyed, and the cables are too thick for positive cutting with explosives. The most economical destruction may be achieved in one of two ways: either by dropping the span leading onto the bridge or by dropping a section of the roadway for the desired length. This length should be determined by an analysis of what capabilities the enemy has for repair in the length of time he is expected to retain the site, particularly using



1 Continuous arch
2 One-hinged arch
3 Two-hinged arch
4 Three-hinged arch

Figure 112. Diagrams showing placement of charges on the various kinds of steel arch spans.

prefabricated bridging. The fact should be recognized that if the main cable is left intact, some type of intermediate support may be improvised from it. Therefore, steps should be taken to produce a large enough gap to prevent such action.

(2) *Minor structures.* On a minor suspension bridge the two vulnerable points to attack are the towers and the cables.

(3) *Towers.* Charges can be placed on the towers slightly above the level of the roadway. A section should be cut out of each part on each tower as shown in figure 113. The charges are placed on each post to force the ends of the cutout section to move in opposite directions. This will prevent ends of a single cut remaining in contact.

(4) *Cables.* Charges should be placed on the cables as close as possible to an anchorage. Extreme care should be taken not to extend the charge more than one-half the distance around the circumference of the cable. With this arrangement, how-

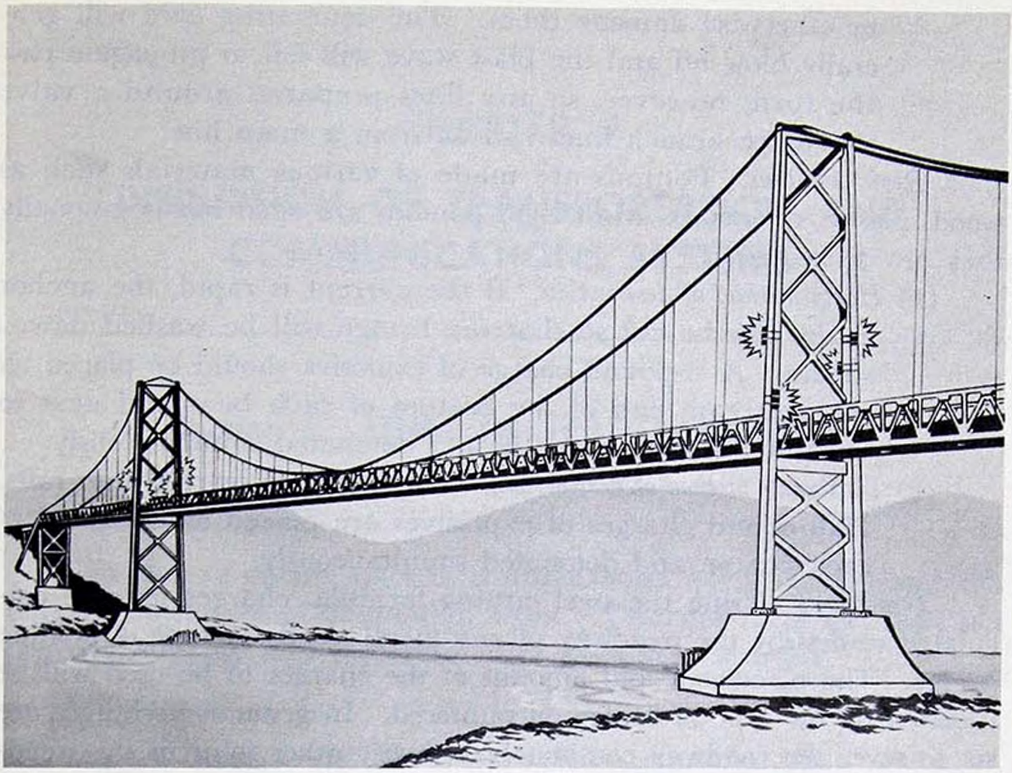


Figure 113. Placement of charges to destroy suspension bridge towers.

ever, charges are bulky, exposed, and difficult to place. Heavy cables are difficult to cut positively. Shaped charges, with their directed force effect, can be used to advantage in cutting a cable.

156. Floating Bridges

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

a. Pneumatic Floats. Pneumatic floats are constructed of rubberized fabric. Each float is made up of airtight compartments, inflated with air.

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

(2) *Delibrate method of destruction.* The floats may be punctured by small arms or machinegun fire. This requires a considerable volume of fire because there are a 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 of the ponton. One strand will suffice to cut most material; two may be required for heavier material. If the detonating cord can be strung under water, it insures a better cut due to the tamping effect of the water. In addition, one turn of detonating cord around the inflation valves will cut them off at the neck

or otherwise damage them. The detonating cord will generally blow off and the blast wave will fail to propagate past the turn, however, so any lines prepared around a valve should be branch lines run off from a main line.

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

(1) *Hasty method of destruction.* If the current is rapid, the anchor cables can be cut so that the bridge will be washed 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. Half-pound charges of explosives are placed at each end of each ponton and detonated simultaneously.

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

157. Bailey Bridges

A basic charge of 1 pound placed internally will cut the upper and lower chords. A ½-pound charge is sufficient to cut the diagonals and the sway bracing.

a. Bridge in Place.

(1) The bridge is cut in one or more places by cutting panels on each side of the bridge, including the sway braces in the panel sections so cut. 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 junction line of the stories.

(2) For further destruction, charges are placed on the transoms and the stringers. The decking is to be stacked and burned.

b. Bridge in Storage or Stockpiles. The destruction must prevent enemy use of the bridge as a unit and of its parts for normal or improvised construction. To prevent reconstruction of a complete bridge, one essential component that is not easily replaced or improvised is to be destroyed. This component must be the same throughout the theater so replacements cannot be obtained from other sectors. The panel is the only component fulfilling these conditions. To make the panel useless, the female lug in the lower or tension chord is to be removed or distorted. All panels are to be destroyed before attacking any other component parts.

CHAPTER 9

DISRUPTION OF TRANSPORTATION AND COMMUNICATIONS SYSTEMS

Section I. LINES OF TRANSPORTATION

158. General

Disruption of enemy lines of transportation is one of the most important objectives of demolition work. Destruction of the road net prevents supplies and materials from reaching the front.

159. Highways

a. Bridges. Bridges are one of the major vulnerable points of a highway system and the demolition of bridges effectively disrupts the system. Bridge demolition methods are described in chapter 8.

b. Culverts. The destruction of small culverts in shallow fills rarely delays the enemy for any appreciable length of time. Widespread culvert destruction, however, is probably worthwhile when time and explosives are available, for such activity will delay the enemy and will absorb a great deal of his engineer effort.

c. Road Craters. Blowing road craters (pars. 128–137) is another method of interrupting highway travel.

d. Fords. Most streams can be forded during the greater part of the year; and, while fords cannot be maintained under heavy traffic, they do provide crossing and support of advance elements until a bridge is repaired or built.

e. Cut and Defiles. In mountainous or hilly country, road cuts may be blocked quickly and effectively by placing several pieces of equipment in the cut and defiles and destroying them, or by blocking debris onto the road from the slopes above it.

f. Abatis. An abatis (a barricade of trees that have been felled across the road) can be employed to good advantage in thickly wooded areas. The charges for felling the trees are computed with the external timber cutting formulas. The object is to break the trees and cause them to fall across the roadway, but to have them remain attached to their stumps so that they must be cut loose before they can be removed.

g. Effective Road Blocks. It is important to recognize that road blocks, to be effective, must be placed in defiles that will be difficult for the enemy to bypass. Also, all roads of the network must be blocked if the enemy is to be halted even temporarily.

160. Railroad Tracks and Roadways

a. Tracks.

(1) *Destruction with explosives.* Railroad weak points are curves, switches, frogs, and crossovers. These points may each be easily destroyed with a small amount of explosive. Placement of charges is shown in figure 114. A length of single track can be destroyed rapidly by a detail of men with a push car, ¼-ton truck, or other vehicle, with explosives, blasting caps, fuzes, fuze lighters, and sandbags. Several men 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 tamp them well with sandbags. Tamping is not required to break the rail, but will result in a longer length of rail being destroyed. Other men of the detail follow about 250 yards behind the vehicle to light the fuzes. This amount of destruction should be repeated at about 1½-mile intervals. This type of destruction will prob-

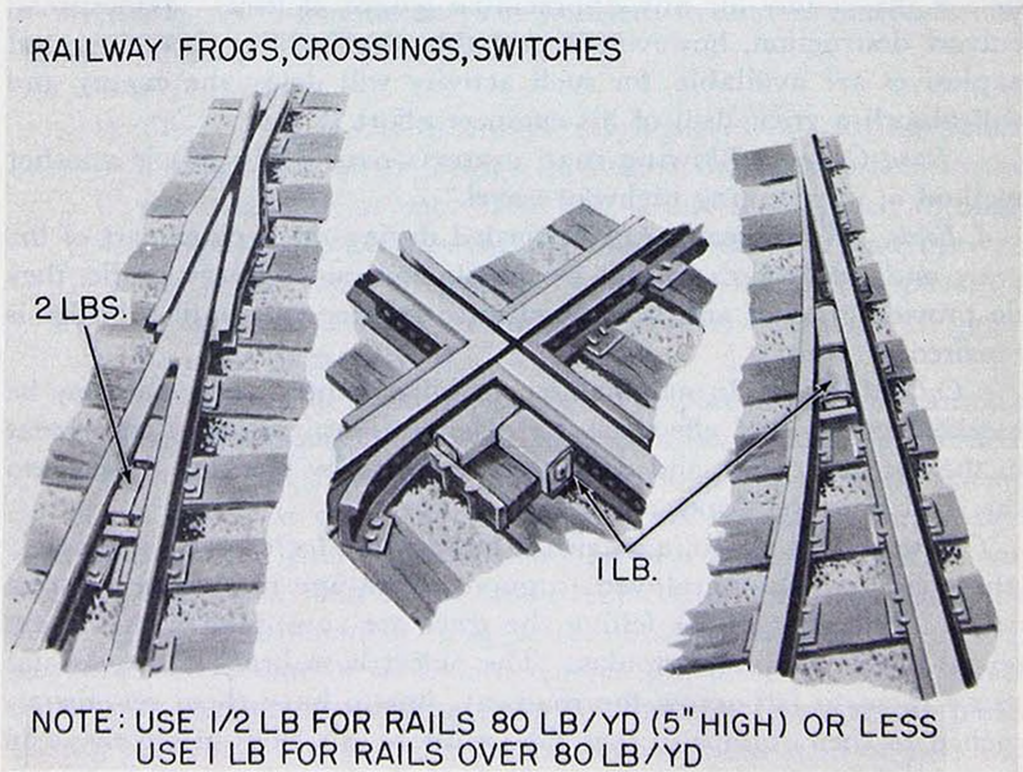


Figure 114. Placement of charges for demolition of railroad switches, frogs, and crossovers.

ably cause tools and equipment of the repair crew to have to be reloaded between worksites. 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 causes more delay in repairing the track than concentrating all of the destruction along one 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.

(2) *Other destruction methods.* Tracks can be rendered unserviceable without the use of explosives by overturning sections on embankments or fills; by 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 can be piled and burned.

b. Roadbeds. Roadbeds are damaged by the same methods used to make road craters and antitank ditches.

161. Tunnels

a. General. Railway and highway tunnels usually constitute vital points of exit or entry to strategic industrial or military areas and would appear to be vulnerable to demolitions and therefore desirable targets. Experience and tests have proven that tunnel demolitions with hastily placed conventional explosives is impossible unless huge quantities of explosive are used. When demolition chambers exist and time, men and equipment are available considerable damage to tunnels can be accomplished with reasonable amounts of explosive.

b. 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 which is transmitted to the rock or is retained in the concrete and the consequent movement of broken fragments which may permit their being dislodged and dropped into the tunnel.

c. Hasty Demolitions. Hasty demolition of tunnels with reasonable amounts of conventional high explosives are ineffective and no hasty method has been devised to cause extensive damage to a tunnel. Means of temporarily depriving the enemy usage of a tunnel can be accomplished by breaking and dislodging portions of the tunnel lining with normal breaching charges placed at a number of points and by creating slides at the tunnel portals by use of cratering charges in the slope above them. Nuclear devices of proper size and advantageously placed provide a means of complete tunnel demolition.

d. Deliberate Demolition. Deliberate tunnel demolitions will produce satisfactory results when explosive charges are detonated in prepared chambers in the media adjacent to the inner face of the tunnel, whether it is lined or not. Excessive charges are not required. Maximum damage to be predicted in any tunnel blast is that of obstructing the tunnel with broken rock except for landslides resulting from charges detonated near portals. Secondary damage by fire may 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 to be followed:

(1) *Charge Chambers.* Construction of tunnel charge chambers should be such that each chamber parallels the long axis of the tunnel at or above the spring line (fig. 115). The use of the T-design tunnel charge chamber offers an efficient means of inflicting serious damage to a tunnel. The chambers can 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, is to be fifteen feet. The tunnel charge chamber should be no larger than necessary for convenience of construction and loading and no smaller than 3 ft. wide by 4½ ft. high. Tunnel 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 ft. (fig. 116).

(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 ft. burden (fig. 116). Charges should be placed in this type chamber on 30 ft. centers.

(3) *Stemming.* Stemming, the material with which a borehole or charge chamber is filled or tamped (usually earth filled sand bags), is necessary from the last charge in the T-type chamber to the chamber entrance (fig. 116). Stemming is not necessary between charges within the chamber. The length of the stemming column should exceed the length of burden.

e. Deliberate Demolition of Tunnels with Prepared Charge Chambers. Some tunnels are constructed with chambers or holes made in the roof for the specific purpose of demolishing the tunnel at some future time. The presence of such charge chambers can usually be detected by open brick ventilators over them. If no such ventilators are present, striking the roof of the tunnel with some heavy metallic object until a hollow sound is heard will help in locating any such chambers that exist. When charge chambers are located, the explosives are placed in them and are compacted as tightly as possible. Then the chamber

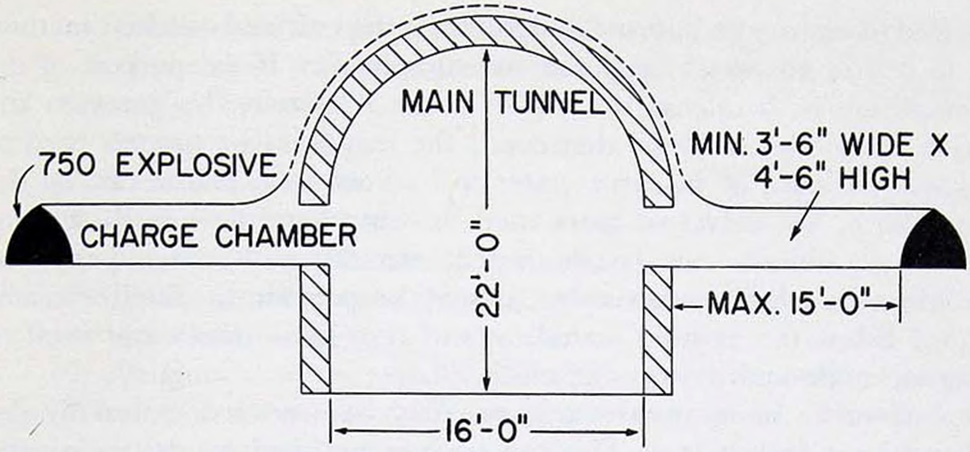


Figure 115. Charge chambers dug at spring line.

is closed and sealed except where the fuze or firing wire passes out of it. Use of sandbag stemming is recommended in all charge chambers in timbered tunnels, since the use of sandbags tends to cause the tunnel timbers to ignite when the charge is detonated.

162. Water Transportation Systems

a. Vessels. Water-borne vessels can seldom be destroyed efficiently by land-based troops, except when these vessels are tied up at docks or piers. The 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 which cannot be bypassed. Channels with retaining walls may be blocked effectively by detonating breaching charges behind the retaining walls.

c. Dams. Since an excessive amount of explosive is generally re-

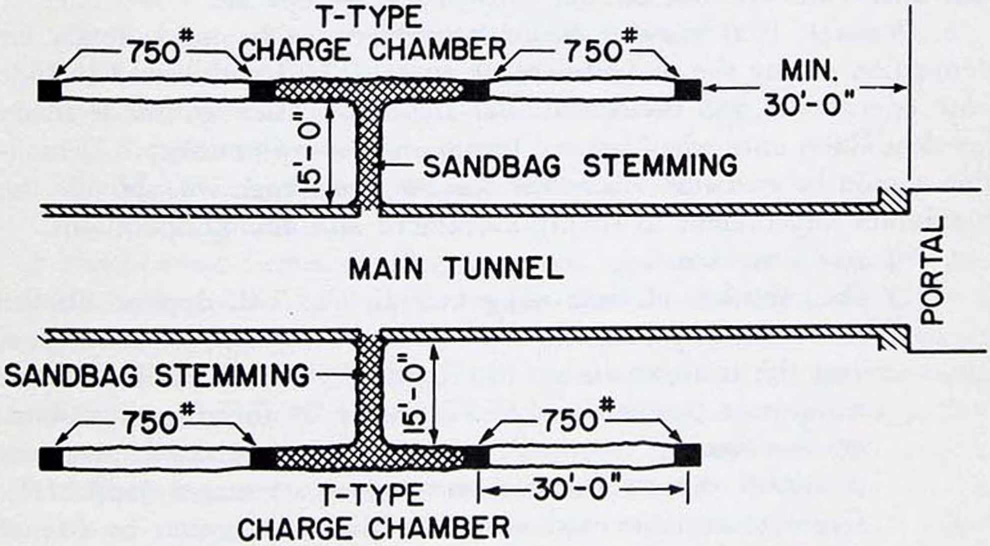


Figure 116. Detail for tunnel demolition.

quired 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, the gates on the crest of the dam may be destroyed; the penstocks or tunnels used to bypass the dam or to carry water to hydroelectric plants can be destroyed; or the valves or gates used to control the flow in those penstocks or tunnels can be destroyed. In dams that are partly or wholly of earth-fill construction, 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 earth fill.

d. Canals. In most cases a canal may be rendered useless by destroying the lock gates. This can be accomplished by destroying the gates themselves, or by destroying the operating mechanisms which control the gates. The electrical equipment, including, perhaps, some pumps, which is used to control the lock gates is the easiest to destroy and should, therefore, be attacked first. If time permits, the gates themselves can be destroyed. The lock walls and the canal walls can be destroyed by using breaching charges or cratering charges behind the walls. In certain highly developed rivers, it may sometimes be advantageous to blast out the control gates on parallel canals. By thus diverting some of the water from the main channel to the canals, the water level in the main channel is lowered. This would be a great help in fording or crossing the main stream.

163. Airfields

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

b. Organized Withdrawal. Airfields which must be made ready for demolition during the preparation for an organized withdrawal include both operational and nonoperational airfields. They are made ready for demolition only when seizure by the enemy is imminent. Demolition should be executed where the resulting wreckage will provide the maximum impediment to enemy movement and enemy operations.

c. Plans for Demolition.

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

field should be prepared before placing any charges. This plan should include the elements listed in *d* below.

d. Elements of Demolition Plan.

(1) Location of charges.

(2) Type of explosives.

(3) Size of each charge.

(4) Priority in preparation of each charge.

(5) Total itemized explosives and other materials needed to effect demolitions included in the plan.

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

e. Priorities for Demolition. The complete demolition of an airfield requires a large amount of explosives and a great deal of time. It is seldom possible, therefore, to destroy an airfield completely. Consequently, it becomes necessary to decide what specific demolition is to be done, and in what order specific operations are to be accomplished. The planning of an airfield demolition should be characterized by great flexibility, particularly in regard to priorities of accomplishment. The order of priority will vary according to the tactical situation. If, for example, it were known that the enemy planned to land fighter aircraft on the airfield in question, destruction of the runways would merit highest priority. But if the enemy were pushing forward on the ground, a hasty withdrawal would probably mean that runway destruction would necessarily be assigned a low priority. The enemy would probably be able to effect any needed repair to the runway before he had use for it and the limited time available could probably be better spent on other demolition activity. The following list suggests an order of priority for airfield demolition, but this list will necessarily be modified to suit the tactical situation:

(1) Runways and taxiways.

(2) Other landing areas.

(3) Routes of communication to the airfields.

(4) Construction equipment at the airfield.

(5) Technical buildings.

(6) Supplies of gasoline, oil, and bombs.

(7) Motor vehicles and unserviceable aircraft.

(8) Housing facilities.

f. Runways and Taxiways. Runways and taxiways are given 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 placing large conduits in all fills. This involves little extra work during construction and provides a means of placing explosives under the runway. Standard deliberate and hasty craters can be used in the demolition of runways and taxiways. Shaped charges may be used to breach thick concrete pavement when speed is essential. Placing individual cratering charges diagonally down the runways or taxiways, or in a zigzag line running diagonally back and forth across the runways, results in more complete destruction. When pierced steel plank or other landing mat is used on an airfield, substantial damage may be done by attaching a large hook to sections of the mat and pulling with a tractor. This should be followed by cratering. A hasty, satisfactory obstacle can be produced by placing 40-pound cans of cratering explosive, spaced every 15 feet across the runway, and buried 4 feet under the ground.

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

h. Aircraft. Unserviceable aircraft should be destroyed by detonating 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.

164. Pipelines

The most vulnerable points of a pipeline system are the storage tanks and the pumping stations.

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

b. Pumping Stations. Booster pumping stations on cross-country pipelines are very vulnerable points. When these are encountered, the pumps and the engines driving the pumps should be destroyed. Large gravel or other solid objects introduced into the pipeline while the pumps are running will damage the moving parts of the pumps, although not to the degree possible with explosives. If time permits, the pumping stations should be burned, after the equipment has been destroyed with explosives.

c. Pipe. The pipe used in pipelines is destroyed only when a scorched earth policy is being carried out because of the large amount of effort necessary to damage the pipe effectively. Junctions, valves, and bends are the most suitable points of attack. This is particularly effective where the line is buried. Another method is to close all valves on a fuel line. The expansion that occurs, even in subzero weather, will break the line.

Section II. COMMUNICATIONS SYSTEMS

165. General

Destruction of communication systems and installations hinders the transmission of messages. These facilities are disrupted by destroying the most vulnerable points.

166. Telephone and Telegraph Wires

Although it is probable that damage to an enemy telephone system or telegraph system can never be extensive, it can have a great delaying effect on the enemy. Telephone and telegraph switchboards and instruments are the best points of attack because they are usually concentrated. Normally, 1-pound charges placed on the lead cables will sever them successfully. Pole lines are strung over long distances and can be destroyed only in spots. They are made temporarily useless by cutting or grounding the wires. Pole lines are completely destroyed by cutting the poles with small external wood-cutting charges and then burning. The wire should be cut into short lengths to prevent its further use.

167. Radio Installations

Radio affords rapid communication between far distant points which otherwise would be without communication. Antenna towers are the weakest part of any radio installation. These towers are usually constructed of steel and are braced with guy wires. They are destroyed by cutting the guy wires and by placing cutting charges against the base of the towers. 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 should be destroyed by mechanical means or by demolition charges.

CHAPTER 10

DESTRUCTION OF EQUIPMENT AND SUPPLIES

168. General

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

b. Destruction Areas. Whenever possible, mobile equipment is demolished where it most effectively impedes the advance of the enemy. Examples of such places that are suitable for destroying equipment 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. Precautions. When material is destroyed by explosives or by weapons fire, the resulting flying fragments and ricocheting bullets constitute a hazardous condition. The destruction must be accomplished in an area free of friendly troop concentrations.

169. Methods of Destroying Materiel

The following methods may be used either singly or in combination to destroy materiel. The actual method or methods used in a given situation will depend upon the time, personnel, and means available.

a. Explosives. All military explosives are effective in destroying equipment. The use of explosives is one of the two preferred methods of destruction.

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

c. Weapons Fire. Use of hand grenades and rifle grenades, antitank rockets, machinegun fire, and rifle fire can be valuable means with which to destroy materiel. The heaviest appropriate available weapon should be used.

d. Thermite Grenades. Flammable material can be destroyed from the heat generated by the thermite grenade. This grenade is designed to destroy equipment as well as the contents of small safes. The material should first be soaked with fuel.

e. Fire. Rags, clothing, or canvas should be packed under and around units to be destroyed. This flammable material should be soaked with gasoline, oil, or diesel fuel and then ignited. Damage from fire may not always be as substantial as is 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 present corrosion. But electrical equipment, including motor or generator armature windings and other wiring, is effectively destroyed by burning. Any parts made from low-melting-point metal may be almost completely destroyed by fire. Burning is frequently a good method to use in conjunction with other methods of destruction.

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

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

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

170. 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 parts should be destroyed. Special attention should be given to those essential parts which are not easy to duplicate or rebuild; and particular care must be taken that the same components are destroyed on each piece of equipment. Unless this is done, it becomes possible for the enemy to assemble a complete unit by cannibalizing parts from several partly destroyed items of equipment. Cannibalization is the transfer of parts from one or several inoperative pieces of equipment to another inoperative piece in order to make the latter operative.

171. Plans

Unit standing operating procedures should include a plan for destruction of equipment and supplies not including medical supplies, which shall be left intact. Such a plan will insure that the maximum and most effective damage being done to materiel and will deny the use of friendly equipment to the enemy. The plan for equipment destruction should outline the required extent of demolition and should include priorities of demolition and methods of destruction. If explosives are to be used, the amounts of explosives required (ch. 6) should be given in the plan. The planning must be sufficiently flexible in its employment 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 of his item of equipment. The demolition plan should cover all equipment issued to the unit.

172. Training

Training does not include the actual destruction of any materiel. It should include 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 destruction of equipment and supplies and with the appropriate method to be used to accomplish the desired destruction. Emphasis should be placed on the correct sequence of operations, as follows:

a. Mechanical damage to vital parts.

b. Use of explosives.

c. Weapons fire, fire, and water.

173. Procedures For Destroying Specific Items of Equipment

Procedures to accomplish the destruction of certain specific items of equipment are thoroughly described in appropriate equipment publications.

174. Combat Equipment

There are various publications on the proper methods of destroying military combat equipment. The destruction of small arms, such as rifles, pistols, machineguns, and mortars, and ammunition is described in the FM 23-series. Methods of destroying armored vehicles and their weapons are discussed in the FM 17-series. The TM 9–700 series outlines proper methods for complete destruction of artillery pieces.

175. Boobytraps

Boobytraps are placed in the debris after destruction is complete, if time permits. See FM 5–31 for the technique of boobytrapping.

CHAPTER 11

DESTRUCTION OF BUILDINGS AND INSTALLATIONS

176. General

Buildings and installations may be destroyed by explosives or other means. The method used and the extent to which demolition is carried out usually depends on the time available.

177. Types of Buildings

a. Masonry or Concrete Buildings. Buildings constructed of masonry or concrete may be destroyed with breaching charges placed in the interior of a building against the base of the exterior walls.

b. Wood or Thin Walled Buildings. Buildings of wood frame construction can readily be destroyed by fire, or by closing all doors and windows and exploding, on the ground floor, a concentrated charge equal to one-fourth pound to 1 pound of explosive per cubic yard volume of the first story. Such buildings may be dismantled, time permitting.

c. Steel Frames. Buildings with steel frames may be destroyed by breaching concrete or masonry to expose vital steel members which are then cut with steel-cutting charges.

d. Workshops. Workshops are destroyed by removing or destroying the fittings and the machinery, and burning or blasting the buildings.

e. 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.

178. Electric Power Plants

Electric power plants are destroyed by cutting the windings of generators and motors or by placing a 2-pound charge inside the casings against the windings and detonating the charge. 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.

179. 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. Reservoirs are destroyed by breaching charges placed in the side walls. Water tanks can be demolished with a charge calculated on the basis of 1 pound of explosive per 100 cubic-foot capacity. The charge is detonated inside the tank when full of water. The water acts as a tamping material. Wells sunk in soft soils may be damaged beyond repair by placing charges to 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 of the well. When possible, the rising main and pump rods are disconnected and dropped to the bottom of the well.

180. Petroleum, Oil, and Lubricant Refineries

POL refineries can be readily destroyed by explosives and fire. Cracking towers, steam plants, and pumps can be destroyed by explosives. Cooling towers and POL stock can be burned.

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
AR 385-63	Regulations for firing Ammunition for Training, Target Practice, and Combat.
SR 75-70-10	Disposal by Dumping at Sea
SM 9-5-1375	Ammunition Explosives, Bulk 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 9-40	Explosive Ordnance Reconnaissance and Disposal
FM 20-32	Employment of Land Mines
FM 31-10	Barriers and Denial Operations
TM 5-220	Passage of Obstacles Other than Minefields
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

APPENDIX II

POWER REQUIREMENTS FOR MULTIPLE FIRING CIRCUITS

1. General

In smaller demolition projects, electric blasting caps are usually connected in series, and the firing accomplished with an electric blasting machine (par. 60). But if a project requires the simultaneous explosion of more separately primed charges than the capacity of the blasting machine will permit, the circuit must be fired with some other power source. Frequently the voltage required to fire a great many caps connected in series will be much higher than any available power source, and other circuits must then be used in order to reduce voltage requirements. The types of circuits are:

a. Series Circuit. A series circuit (fig. 49) provides but one path for the electrical current which is 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 use of too many caps in a circuit increases the hazard of cutoffs in the firing line or cap leads prior to initiation of some caps.

b. Parallel Circuit. A parallel circuit (fig. 51) consists of a pair of main wires (called bus wires) in prolongation of the 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 bus wire. 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 of the parallel system. This condition can be achieved by using identical caps throughout a given parallel circuit.

c. Series-Parallel Circuit. A series-parallel circuit (fig. 52) consists of a number of separate series-connected groups of blasting caps joined in parallel. Thus a series-parallel system is different from a parallel system only in 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 can be achieved by making each branch consist of the same number of identical blasting caps, providing that connections, secondary leads, and cap leads introduce only a negligible amount of resistance or equal resistance in each branch. Where the quantities of explosives will be considerable, long leads should be used to connect the series of caps to the main wires of the circuit in order to reduce the chance of the main wires being cut by a charge before the current reaches the end of the parallel circuit. No more than 30 blasting caps should be placed in any single branch of a series-parallel circuit.

2. Precautions

Observe the following rules in all parallel or series-parallel circuits.

a. No more than one type or make of caps are to be connected in a circuit.

b. Not more than 30 caps are to be connected in each series of a series-parallel circuit.

c. When two or more series are connected in parallel, the same number of caps are to be placed in each series.

d. Particular attention must be paid 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, a check must be made to see that there are no more than 30 caps in each resulting series (rule *b*). If several parallel arrangements are connected in parallel, the result is very likely to be out of balance, and the result is very difficult to check for balance. Consequently such circuits should be avoided. Separate series stages are to be connected in parallel so as to make a series-parallel circuit.

e. In series-parallel circuits, lead wires are used which are identical and approximately the same length. All connections are to be made tight, because loose or faulty connections increase resistance greatly, thereby causing unbalanced circuits.

f. Direct current is to be used 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. Extreme care must be exercised in post-firing inspection. All unexploded parts of the circuits must be located and destroyed.

3. Ohm's Law

To calculate the amount of voltage which must be impressed on a circuit to detonate the blasting caps in that circuit requires the use of the basic law of electricity, Ohm's Law:

$$E = IR$$

where: 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:

$$W = I^2R$$

where: 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 provided to fire special 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 provided should be at least 0.6 ampere per blasting cap. The resistance of a special electric blasting cap is 2 ohms.

6. Resistance of a Circuit

Both the blasting caps and the wire contained in a circuit contribute to the total resistance of that circuit. The total resistance in a circuit is computed from the individual resistances of the blasting caps and the wire which comprise the system. This calculation is not the same, however, for different types of circuits. The resistance of the wire used in a circuit depends upon the size and the length of that wire. Table XIV gives the resistance *per 1,000 feet* of various sizes of copper wire.

Table XIV. 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

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. 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 resistances of all the caps and wire which comprise that circuit or the series-connected branch of the 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 would be able to 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 but one cap) divided by the number of branches. 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 total length of the bus wires but to include the entire 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 explained in *a* above. After computing the resistance of a single branch, the resistance of the entire circuit is computed 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.

7. Calculations For a Series Circuit

Complete calculations for any circuit will involve determining the current (amperes), the voltage (volts), and the power (watts) needed to fire the circuit. Computation of the voltage and of the power will require 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. Using the electrical power formula, $W = I^2R$ (par. 4 this app.), the number of watts of power needed can be found by multiplying the square of the current required ($1.5^2 = 2.25$) by the resistance of the system.

e. Illustrative Problem. A circuit consists of 20 special electric blasting caps connected in series, and 500 feet of the standard 2-conductor, 18-gage firing wire. What are the current, voltage and power requirements to detonate the blasting caps?

(1) Current required=1.5 amperes (*a* above)

(2) Resistance

of 20 blasting caps=2.0×20 =40

of 1,000 feet No. 18 wire (table XIV) = 6. 4

Total resistance =46. 4 ohms

Note. A 500-foot firing wire consists of 2 strands of No. 18 wire each strand being 500 feet long. Hence, 1,000 feet of wire is used in the above computation.

(3) Voltage

$$E=IR \text{ (par. 3 this app.)}$$

$$E=1.5\times46.4=69.6 \text{ volts}$$

(4) Power

$$W=I^2R \text{ (par. 4 this app.)}$$

$$W=1.5^2\times46.4=2.25\times46.4=104.4 \text{ watts}$$

8. Calculations For a Parallel Circuit

a. Current Requirements. The current required for a parallel circuit of special electric blasting caps is 0.6 ampere per blasting cap. This can be expressed in the following formula:

$$I=0.6\ N$$

where: I=total current, expressed in amperes.

N=number of blasting caps which are connected in parallel.

b. Resistance. The resistance of a parallel circuit is computed as outlined in paragraph 6 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 by the resistance of the system.

d. Power Requirements. Using the electrical power formula $W=I^2R$ (par. 4 this app.), the number of watts of power needed can be found by multiplying the square of the required current by the resistance of the system.

e. Illustrative Problem. A circuit consists of 20 special electric blasting caps connected in parallel at 10-foot intervals along a pair of 20-gage bus wires. The bus wires are connected to a 400-foot standard 18-gage, 2-conductor firing wire, which is, in turn, connected to the power source. What are the current, voltage, and power requirements to detonate the blasting caps?

(1) Current

$$I=0.6\ N \quad (a \text{ above})$$

$$I=0.6\times20=12 \text{ amperes}$$

(2) Resistance (refer to table XIV for wire resistances)

of firing wire $=\frac{800}{1,000}\times6.4$ =5. 1 ohms

of bus wires $=\frac{380}{1,000}\times10.2\times\frac{1}{2}$ =2. 0 ohms

of blasting caps=2.0÷20 =0. 1 ohms

Total resistance =7. 2 ohms

(3) Voltage

$$E = IR$$

$$E = 12 \times 7.2 = 86.4 \text{ volts}$$

(4) Power

$$W = I^2R$$

$$W = 12^2 \times 7.2 = 144 \times 7.2 = 1{,}037 \text{ watts}$$

Note. The firing wire length is computed as shown in paragraph 7*e*(2) of this appendix. The bus wire length 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 required by paragraph 6*b* of this appendix.

9. Calculations For a Series-Parallel Circuit

a. Current Requirements. The current required for a series-parallel circuit of special electric blasting caps is 1.5 amperes per circuit branch. This can be expressed in the following formula:

$$I = 1.5N$$

where: I = total current required.

N = number of separate series-connected branches which are in parallel.

b. Resistance. The resistance of a series-parallel circuit is computed as outlined in paragraph 6*c* 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 by the resistance of the system.

d. Power Requirements. Using the electrical power formula, $W=I^2R$ (par. 4 this app.), the number of watts of power needed can be found by multiplying the square of the required current by the resistance of the system.

e. Illustrative Problem. A certain series-parallel circuit is composed of 10 branch lines connected in parallel. Each branch line is composed of 30 special electric blasting caps connected in series. The wire used includes 400 feet of 20-gage bus wire and 500 feet of standard 18-gage, 2-conductor firing wire. What are the current, voltage, and power requirements for detonating this system of 300 special electric blasting caps?

(1) Current

$$I = 1.5N \qquad (a \text{ above})$$

$$I = 1.5 \times 10 = 15 \text{ amperes}$$

(2) Resistance

(*a*) of each series $= 30 \times 2 = 60$ ohms

(*b*) of the entire system

of the branches $= 60 \div 10$	$= 6$ ohms
of the firing wire	$= 6.4$ ohms
of the bus wire $= \frac{400}{1{,}000} \times \frac{1}{2} \times 10.2$	$= 2.0$ ohms
Total resistance of the system	$= 14.4$ ohms

Table XV. Maximum Circuit Capacities of Various Power Sources

	1	2	3	4	5	6	7	8	9	10
	Circuit design	Total number of caps in circuit	Power source							
			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

(3) Voltage

$$E = IR \text{ (par. 3 this app.)}$$
$$E = 15 \times 14.4 = 216 \text{ volts}$$

(4) Power

$$W = I^2R \text{ (par. 4 this app.)}$$
$$W = 15^2 \times 14.4 = 225 \times 14.4 = 3{,}240 \text{ watts}$$

10. Calculated Voltage Drop

In each of the examples given above the voltage drop in the blasting circuit was calculated by the use of Ohm's Law. If the calculated voltage drop exceeds 90 percent of the available voltage it is recommended that a change be made in the circuit, that is, that the resistance of the circuit be decreased or the voltage available be increased.

11. Capacity of Power Plants

a. Determining Capacity of Power Plants. The nameplate amperage and voltage rating of a power plant or generator can be used to determine whether the power source is suitable for firing an electric circuit which has been computed by the above methods. Frequently, however, it may be desirable to determine how large a circuit can be fired with current from a given power plant. Table XV 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) The amperage of the generator is divided by 1.5 to get the number of separate series-connected branches that can be hooked in parallel.

(2) Ninety percent of the voltage of the generator is divided (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 can be in the circuit.

(3) The firing-reel and connecting-wire resistance is subtracted from the maximum allowable resistance of caps for a series-parallel circuit.

(4) To calculate the maximum number of caps per series, the allowable resistance of the caps in the circuit is multiplied by the number of series and divided by the resistance of one cap (2.0 ohms).

(5) Illustrative problem: A 3-kw, 220-volt, 13½-ampere generator is available as a power source for blasting operations. Assuming that 500 feet of standard 2-conductor firing wire and 200 feet of 20-gage connecting wire were used to join the blasting caps, how many special electric blasting caps could be fired with this power source and how should the circuit be arranged?

Number of series to be included in circuit$=\frac{13.5}{1.5}=9$ separate series

Allowable resistance of circuit$=\frac{.90\times 220}{1.5\times 9}=14.6$ ohms

Resistance of firing wire$=6.4$ ohms

Resistance of connecting wire$=\frac{1}{2}\times\frac{200\times 10.2}{1{,}000}=1.0$ ohms

Total resistance of wire$=6.4+1.0=7.4$ ohms

Allowable resistance of caps for a series-parallel circuit$=14.6-7.4=7.2$ ohms

Number of blasting caps per series$=\frac{9\times 7.2}{2}=32.4$ caps per series

Paragraph 2*b* of this appendix states that no more than 30 caps should be connected in each series of a series-parallel circuit. Therefore, the circuit should be arranged in 9 series of 30 caps each, in parallel.

b. Use of Storage Batteries and Dry Cells. Storage batteries and dry cells can be used to fire an electric circuit. To determine how large a circuit can be fired with current from a battery or dry cell, the procedure outlined in paragraph 11 of this appendix should be used.

Caution: For safety, disconnect the battery terminal prior to disassembly of equipment where there is danger from shorting across the battery circuit. In reassembly of equipment, the battery terminal connection is made last.

APPENDIX III

USE OF LAND MINES, AERIAL BOMBS, AND SHELLS AS DEMOLITION CHARGES

1. General

When land mines, aerial bombs, and shells are used as demolition charges, special precautions must be taken to protect personnel from 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 from captured or friendly supply stocks or, in the case of land mines, may be mines recovered from enemy or friendly minefields. In no case should unexploded dud shells or bombs be used for demolition purposes.

2. Land Mines

a. General. United States and foreign land mines are described in detail in FM 20–32 and TM 5–223. Only defuzed mines should be used in demolition charges. Fuzed mines recovered from minefields may be sensitive and may detonate with even normal handling. The use of enemy mines salvaged from minefields or dumps is governed by directives from the headquarters of the theater concerned.

b. Charges. Most mines contain charges equal to approximately half their total weight. In calculating charges when using mines, only this explosive weight is considered. Normal explosive quantities may be used for cratering or pressure charges with mines, but, because of poor contact with mines against irregularly shaped objects, it may be necessary to increase cutting charges considerably. Test shots will determine the results to be expected under given conditions.

c. Priming. Land mines are detonated by exploding one-half pound of explosive on the pressure plate of the mine. 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. General. General-purpose aerial bombs can be used satisfactorily for demolition charges but are most effective as cratering charges. 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. No other type bomb should be used.

b. Charges. The explosive content of bombs is approximately half their total weight. Table XVI gives the weight of high explosive contained in general-purpose bombs of various sizes. When detonated, approximately 20 percent of the explosive effort of the bomb is expended in shattering the bomb case. The chief value of bombs for demolition work is in cratering charges. Their shape makes them inefficient for demolition requiring close contact between the explosive and the material to be blown.

Table XVI. Explosive Content of General-Purpose Bombs

Bomb	Total weight (lb)	Explosive weight (lb)
1. 100-lb GP, AN–M30A1	115	57
2. 250-lb GP, AN–M57A1	260	125
3. 500-lb GP, AN–M64A1	525	266
4. 1,000-lb GP, AN–M65A1	990	555
5. 2,000-lb GP, AN–M66A2	2, 100	1, 098
6. 3,000-lb GP, T–55	2, 605	1, 710

c. Priming. Bombs under 500 pounds are detonated by firing a 5-pound explosive charge in good contact with the bomb in the middle of the bomb case. Bombs of 500 pounds or more are detonated by a 10-pound charge similarly placed. Fuzes are not placed in the bombs and detonating charges should not be placed against the nose or tail. To insure detonation, large bombs are 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 weighs 33 pounds, but contains only 5 pounds of explosive. The 155-mm howitzer HE shell contains but 15 pounds. Shells up to 240-mm are detonated by 2 pounds of explosive placed in good contact with the shell, just forward of the rotative band. To insure complete detonation, a charge should be placed on each shell to be exploded. The universal destructor M10 (par. 52) can 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 caps to the destructor M10 as required.

APPENDIX IV

SUMMARY OF FORMULAS FOR EXPLOSIVES

1. Steel-Cutting

a. Structural Members (par. 114*a*).

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

where: P = pounds of TNT required
A = cross-sectional area, in square inches, of the steel member to be cut.

b. Other Steel Members (par. 114*b*).

$$P = D^2$$

where: 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. 118*a*).

For Composition C4* $P = \frac{C^3}{30}$ (for $C = 5\frac{1}{2}$ feet to $C = 9\frac{1}{4}$ feet),

where: P = pounds of explosive and
C = circumference of tree or timber in feet. When the circumference exceeds 9¼ feet (36 in. diameter trees), cutting with explosives is not reliable unless excessive amounts of explosives are used.

b. Internal Charges, Tamped. (par. 118*c*)

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

where: P = pounds of explosive required, and
D = diameter, or least cross-sectional dimension in inches.

3. Pressure Charges to Destroy Simple Span Reinforced Concrete T-Beam Bridges

(par. 121)

$$P = 3H^2T$$

where: P = pounds of TNT required for each stringer
H = height of stringer, including thickness of roadway, in feet
T = thickness of stringer in feet.

*When TNT is used, increase P by ⅓.

However, the values of H and T, if not whole numbers, are usually rounded off to the next higher quarter-foot dimension; and neither H nor T is ever considered to be less than 1 in the formula.

Note. Increase calculated charge P by one-third if not tamped.

4. Breaching Charges

a. Size of Each Charge (par. 125*a*).

$$P = R^3KC$$

where: P=pounds of TNT required
R=breaching radius in feet
K=material factor (table X)
C=tamping factor (fig. 85).

Note. Add 10 percent to the calculated charge whenever P computes to be less than 50 pounds.

b. Number of Charges (par. 126*b*).

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

where: N=number of charges
W=width of pier, slab, or wall, in feet
R=breaching radius, in feet.

When the calculated value of N contains a fraction less than ½, the fraction is disregarded, but when the calculated value of N contains a fraction of ½ or more, the value is rounded off to the next higher whole number. An exception exists to this general rule in the case of calculated N-values between 1 and 2. In this instance, 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. 130). Forty-pound charges in 5-foot boreholes, alternated with 80-pound charges in 7-foot boreholes. 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. 131). Use 10 pounds of explosive per foot of borehole, placed in holes of equal depth. Boreholes are placed on 5-foot centers with the depth varying from 2½ to 5 feet.

6. Breaching Hard-Surfaced Pavements
(par. 129)

Use charges equal to 1 pound of explosive per 2 inches of pavement. Tamping should be equal to twice the pavement thickness.

7. Computation of Minimum Safe Distances

(par. 43)

a. For charges less than 27 pounds the minimum safe distance is 900 feet.

b. For charges from 27 to 500 pounds the safe distance formula is:

$$\text{Safe distance in feet} = 300 \times \sqrt[3]{\text{pounds of explosives}}$$

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. If an explosive other than TNT is used, the value of P should be adjusted (table I) for the type of explosive used, but only when external charges are computed from one of the formulas for the following:

(1) Steel.
(2) Timber.
(3) Breaching.
(4) Pressure.

INDEX

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By Order of *Wilber M. Brucker*, Secretary of the Army:

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PMST Mil Sch Div Units (1)
Gen Dep (1)
Engr Sec, Gen Dep (1)
Engr Dep (1)
Div Engr (1)
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AMS (2)
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  (Res) (1) Units organized
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  5-16 (2)
  5-17 (5)
  5-36 (2)
  5-37 (5)
  5-48 (2)
  5-56 (2)
  5-57 (2)
  5-59 (2)
  5-67 (2)
  5-96 (2)
  5-97 (2)
  5-137 (2)
  5-138 (2)
  5-139 (2)
  5-157 (2)
  5-167 (2)
  5-192 (2)
  5-215 (2)
  5-216 (2)
  5-217 (2)
  5-218 (2)
  5-226 (2)
  5-262 (2)
  5-266 (2)
  5-267 (2)
  5-278 (2)
  5-279 (2)
  5-301 (2)
  5-312 (2)
  5-316 (2)
  5-317 (2)

5-324 (2)
5-328 (2)
5-329 (2)
5-344 (2)
5-346 (2)
5-347 (2)
5-348 (2)
5-349 (2)
5-367 (2)
5-372 (2)
5-376 (2)
5-377 (2)
5-387 (2)
5-412 (2)
5-416 (2)
5-417 (2)
5-464 (2)
5-500 (AA-AC) (2)
5-526 (2)
5-527 (2)
9-17 (1)
9-22 (1)
9-47 (1)
9-86 (1)
9-87 (1)
9-337 (1)
9-510 (AA-AC) (1)

NG: State AG (3); units—same as Active Army except allowance is one copy to each unit.

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For explanation of abbreviations used, see AR 320-50.

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